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THE BURDEN OF REPRODUCTION*

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In the primitive forms of unicellular life, reproduction is attained by the simple expedient of cell division. Such forms of life are extremely sensitive to environment, the mortality is tremendous and the species is perpetuated owing to the incalculable rapidity of reproduction under favorable surroundings.

Higher in the scale of life, as in some insects, there is a period of development of the young of as much as one to several years during which time it is incapable of reproduction. When the individual finally reaches adult life and sexual maturity, the female pairs, lays her eggs and dies; a single reproductive act terminates the life of the parent. Again the mortality of the young is immense and the continuation of the species is assured only by the vast number of eggs produced.

Domestic mammals present a quite different picture. The heifer calf has at birth an estimated average of about 75,000 ova or eggs in each ovary. If the heifer is kept for breeding purposes, it is highly improbable that more than one in ten thousand of these eggs will mature and be discharged, as indicated by the occurrence of 'heat'. So far as I am able to estimate, the heifer retained for breeding produces upon the average less than five calves, in order to do which she copulates more than ten times. It is fairly certain that in a vast majority of cases, when a cow is bred while properly in heat, to a bull of even very low fertility, some one of the billions of spermatozoa meet with, and fertilize the egg, but more than half of such fertilized eggs die and disappear without pregnancy having become recognizable. This is called *sterility*. In those animals which regularly give birth to a single young, like the cow or mare, the common necessity for breeding two or more times before recognizable pregnancy occurs, causes little anxiety upon the part of the owner. When the delay is greatly prolonged the breeder realizes his loss. In comparison with the mare and cow, the sow is not often classed as sterile. More than half the fertilized eggs perish, but the pregnancy continues because of the presence of some living embryos and the disappointment occurs in the size of the litter.

When, in an animal normally giving birth to a single young, the fetus dies and is expelled when of sufficient size that it is observed by the owner it is called *abortion* and causes a panic. If the fetus is born only to die early from disease acquired in the uterus it is designated scours, pneumonia or according to some other symptom and is regarded as a misfortune.

The breeder takes his losses in three or more instalments and fails to comprehend the total or the intimate relationship between the various classes

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of defeat. The larger domestic animals, horses and cattle, reproduce very slowly. With the exception of the misfortune of twins, the maximum is one young per annum, with the average much nearer to one healthy young in two years.

Regardless of the fact that so far as can be determined more than half the fertilized eggs perish and disappear unobserved, and that regrettable losses occur from abortion, and of the new-born from disease acquired in the uterus, the ratio of fertilized eggs which ultimately develop into adult animals is far greater than in the lower forms of animal life. This is due to the mammalian plan of reproduction. Taking the cow as an example, when in heat there is a fully developed egg in one of her ovaries ready to be discharged. When she is bred, billions of spermatozoa are discharged into her vagina and vast numbers of these move toward the ovary and have reached the immediate vicinity when the egg is discharged so that if both individuals concerned are reasonably healthy, fertilization is virtually inescapable. The fertilized egg passes down the narrow fallopian tube to the uterus where it halts for a period of nine months to undergo development. During this interval the uterus is efficiently closed to the exterior by means of a special barrier or plug of mucus formed in the mouth of the uterus. During this period the danger from bacteria is limited to those already in the uterus and to those which may enter later through the blood stream. The ideal time during which the fertilized egg is detained in the uterus is about 285 days, during which period the microscopic organism develops into a fetus weighing fifty to one hundred and fifty pounds. It is then born with all the organs developed which it is ever to possess. Most of the organs have already functioned before birth, the lungs are ready to work at the first moment of need and its locomotive system enables it to move freely in quest of food or water or to elude its enemies. The mother supplies for a time adequate food and protection.

The new-born foal and calf stand in the front rank in the attainable security of their lives. This safety has been attained at the expense of the mother which bears a constant and heavy burden during pregnancy and nursing. The plan is security, rather than rapidity of reproduction. The problem of the animal husbandman is not the rapidity of the production of mammalian eggs and their fertilization—that has been essentially immutably fixed—but the promotion of the security of the new individual. It is his task to see that two healthy individuals are mated, that a healthy egg shall be fertilized by a healthy male cell, and the resulting new organism develops within a healthy uterus. The breeding animal must be capable of bearing the burden of reproduction safely.

It is only within recent years that the problem of reproduction in domestic mammals has taken its place in the front rank, both scientifically and economically. The breeder and the state have been concerned almost wholly with such animal plagues as anthrax and foot-and-mouth disease, but the scene has shifted until today the interferences with reproduction constitute a problem of the first magnitude.

Early in the awakening of the public to the seriousness of the breeding situation I took the position in my writings that the foundation for the control

of interferences with reproduction lay in the mating of two sexually healthy individuals. The proposal was largely ignored alike by breeders and veterinarians. Then as now attention was focussed upon the observed expulsion by the female, of a dead fetus. Abortion was made the center about which all interferences with reproduction revolved. Abortion was, and still is, attributed to an infection acquired by the female during pregnancy. In so far as such theory is correct, the doctrine that only sexually healthy individuals should be mated is of no fundamental importance. It could no more control sterility, abortion and retained afterbirth, if the infections causing them invade the uterus after conception, than could the mating of sexually healthy individuals control foot-and-mouth disease. Accordingly veterinarians and breeders have sought to control breeding diseases through quarantine upon erroneous basis, by the use of dead and of living abortion bacilli, and by an endless number of abortion-sterility nostrums.

Diseases of the reproductive organs differ markedly from most other maladies familiarly known. An individual of either sex may be seriously or hopelessly diseased sexually without visibly disturbing its general health. The reproductive functions may also, at the will of the breeder, be indefinitely deferred without material peril to the breeding power.

If the proposal be accepted, that successful reproduction must be based upon the mating of two sexually healthy individuals, it becomes essential to learn the most reliable standards by which sexual health may be measured, how acquired and maintained. The standards for measuring sexual health, as commonly applied by breeders and veterinarians, are extremely inaccurate and misleading. Taking the cow as an example, highly influential writers repeatedly assert that a given cow produced two normal, single, calves during one calendar year. If 'produced' is to signify the fertilization of the egg, the development of the fetus and the birth of a mature, healthy calf, which it certainly should mean, the production of two calves by a cow in one year is a mathematical impossibility—two pregnancies of 285 days each can not be crowded into one year of 365 days. Numerous eminent writers in this field also state that a given cow 'calved correctly' or 'normally' although the fetus was dead when expelled or extracted, so that as a matter of fact no birth occurred; and the cow died from retained afterbirth. The literature in this field is saturated with such inaccuracies and renders it highly desirable that some fairly accurate and instructive standard be established for measuring the health of breeding animals.

The following standard is suggested for cattle:

1. Pregnancy shall follow a single service.
2. The duration of pregnancy is 285 days with a variant of five days above or below that figure.
3. The fetus is expelled without human aid within one hour after the commencement of labor.
4. The afterbirth drops away within two hours after the birth of the calf.
5. No recognizable discharge occurs from the genital organs, beyond a small amount of blood and lymph, for two or three hours following the dropping away of the afterbirth.

6. The calf, when expelled, shall be clean and free from stains or other indication of diarrhoea before birth. It shall be lively, active and on its feet without aid within an hour. It shall not break down within 48 hours from diarrhoea or other disease referable to infection within the uterus.
7. The afterbirth shall be free from important evidence of disease.

The ideals proposed are intimately correlated and each needs to be duly weighed in measuring the degree of sexual health. A cow may make a fair recovery from retained afterbirth and her calf may be apparently well, but when closely studied, upon a series of cases, it will be found that retained afterbirth ordinarily leaves a mark upon both cow and calf. A fetus may suffer from severe illness while in the uterus and, as occurs in diseases of adults, may so far recover that it may be born apparently healthy. A calf may carry in its organs serious infection which it acquired in the uterus, or it may be invaded by the same, or similar, infection soon after birth. The calf may, and often does, so far recover from such disease before it reaches sexual maturity that it may breed satisfactorily, but however complete the apparent recovery, the rule, so far as is known, is that the animal remains permanently more susceptible to disease than one which has been constantly healthy throughout its life from the moment when the egg was fertilized.

But diseased fetuses and new-born calves by no means all recover. Thus a heifer was repeatedly bred and probably expelled, unobserved, a number of embryos or small fetuses. Finally, at four years of age, she gave birth to an evidently diseased bull calf. His scrotum was greatly enlarged, as indicated in Figure 1, hot and painful. There was a discharge from his navel of a thin, dirty-looking pus; he was very thin, stiff and weak. A post-mortem examination showed, besides numerous other changes, complete destruction of both testicles through the formation of abscesses in them. At least two of the specifications above proposed as proof of healthy reproduction had been grossly violated; recognized conception had not occurred at a single service (1), and the calf was not healthy when born (6).

This is not at all a solitary example. Many calves are so badly diseased at birth that they die within 24 to 48 hours. Others live and some of them so far recover as to be able to breed while others remain permanently sterile. Among new-born domestic mammals, dairy calves are the most artificially reared and, as should be logically expected, are, upon the average, the most unhealthy. The mortality of dairy calves from diarrhoea, pneumonia and allied diseases is enormous. Many others are critically diseased but apparently recover. Along with these, the vast majority of those not markedly sick, when 5 to 10 days old, lose the ideal lustre of their coats, their feces are sticky and adhere to the tail, the calf becomes pot-bellied and in general falls below the ideal of health and vigor. When four to six months old they mostly regain the outward signs of health. Then follows, in many dairy herds, an interval of 9 to 12 months before the heifers are bred and compelled to assume the burden of reproduction. If the health of the heifer is ideal, her strength, from the moment when the egg from which she originated was fertilized up to the day she is bred, is wholly available for

Figure 1. Calf from a heifer with badly diseased uterus. She had to be bred repeatedly for more than a year before she became recognizably pregnant. The calf was born with inflammation of the navel and testicles. The hair about the navel is badly soiled from pus; the testicles are greatly enlarged, constituting abscesses.

growth and development of the strength desired for the task of reproduction. If her health has been depressed during the nine months in the uterus and four or five months after birth while sick or in bad health, the period of time during which she may profitably develop strength and the power to resist disease hovering about reproduction, has been curtailed at least one half, and she experiences the further handicap, that, in order to breed well, she must destroy, or bring under efficient control, those infections or other causes of disease which have been at work. The heifer thus has a task of large proportions.

Beller, of the Imperial Health Office at Berlin, and Wagner of the agricultural school at Hohenheim, Germany, have quite clearly shown, after extensive investigations, that calves apparently healthy at birth, as well as those which are definitely diseased, have in their fetal fluids (the 'waters' of the calf), in the blood of the navel veins and in other organs and tissues, various bacteria which, under certain conditions, may cause disease. A large proportion of calves, however, if properly fed and handled, hold such bacteria under control. Other calves, less favorably handled or having in their organs more virulent bacteria, become seriously or mortally sick.

Conflicting views arise regarding the nature of diarrhoea and penumonia in young calves, some holding that it is of fetal origin, others, that it is due to improper feeding and care after birth. There is little ground for denying either source, nor is the question itself so vitally important as is the fact

TABLE 1.—*Changes in the breeding efficiency of heifers in first breeding year, in a large herd, following modifications in the care of heifer calves, by which their health was advanced.*

Period covered	Heifer calves born	Died of scours or pneumonia	Died of other causes	Sold for veal	Pregnant or too young to breed	Net number available for study	Conceived	Calved	Aborted
1909-1912	593	184	113	118	0	178	170	95	75
40 months		31%	19%	19.9%		30%	95.5%	53.4%	42.1%
1912-1916	904	203	71	0	402	231	225	203	22
50 months		22.4%	8%			45.8%	97.4%	90.2%	9.8%

that such disease is common and causes great loss to the breeder whether the calf dies or reaches breeding age incapable of satisfactorily bearing the burden of reproduction. It is a common observation that, in large dairy herds, where calf diseases are severe, those heifers which survive and apparently recover, prove later to be poor breeders, require numerous services before recognizable pregnancy occurs, largely abort during first pregnancy, those which calve do so largely at less than the ideal 285 days, many have retained after-birth, and in general they violate most of the principles proposed above for measuring healthy reproduction. The idea is well illustrated in table 1.

In this large herd of 500 milk cows, diarrhoea and pneumonia were taking one third of the heifer calves and all were seriously ill or in definitely bad health, and of those which lived to become definitely pregnant, 42.1 per cent aborted. The feeding of calves was changed in 1912, the mortality decreased, the general health was better and, when they reached breeding age, the abortion rate in first pregnancy dropped from 42.1 per cent to 9.8 per cent. That is but part of the story. The heifers of the second group yielded far more milk than the first. There had been no recognizable change in the handling of the two groups except for the calf feeding. They were kept in the same quarters, had essentially the same attendants, and, so far as is practicable in a herd of the size, were bred to the same bulls. The evidence is so massive and the change in production so striking that there is certainly ample ground for concluding that the care of the young calves had a tremendous influence upon their sexual health at breeding age. The ratio of sterility and abortion in the adults had not changed.

The point may be further illustrated by observations in another herd as shown in table 2.

TABLE 2. *Observations upon a group of heifers arriving at breeding age in 1912 with breeding history to 1916.*

No.	Born	1912	1913	1914	1915	1916			
1	12— 6—09	A					Destroyed account emphysema of fetus and gangrene of uterus.		
2	10— 6—09	A					Died of metritis.		
3	10— 6—09	A					Slaughtered, sterile.		
4	10—30—10	A					Slaughtered, sterile.		
5	9— 6—10	A	A	S			Slaughtered, sterile.		
6	9—29—10	BX	S	B.H	S	B	Slaughtered, sterile.		
7	11— 6—10	A	B.B.				Died, metritis.		
8	4—26—11	H					Slaughtered, sterile.		
9	7—20—10	B					Retained afterbirth. Sold. Inefficient.		
10	1— 1—11	B	B				Sold. Udder disease.		
11	2— 5—11	A	B	B	B		Sold, inefficient.		
12	9—22—10	A	H	B			Died 1915. Indigestion.		
13	10— 5—10	H	B	H	B		Sold.		
14	10—20—10	H	S	B	B	B			
15	10—18—10	B	H		B.B.		H. born 1913 - died.		
16	10— 5—10	A	B	B	B	H			
17	10— 5—10	A	H	B					
18	12— 9—10	A	H	H	H	B	H. born 1914 - died.		
Totals		H 3	4	3	1	1	12	Died	4
		B 4	6	6	6	3	25	Slaughtered, sterile	5
		A 11	1	0	0	0	12	Discarded, possibly fertile	4
								On hand 1916	5
									18

Original females remaining	5
Heifers of breeding age	7
	12
Heifers under breeding age	6
Total females	18

H—Heifer.
B—Bull.
A—Abortion.

In table 2 is shown the breeding history of 18 purebred heifers over a period of four breeding years. The establishment had, for some years, attempted to grow its calves under pesthouse conditions—in a dark, damp, overcrowded, illy ventilated basement, amidst swarms of flies. The mortality amongst young calves was appalling. The abortion rate in first pregnancy averaged 50 per cent. A study of the table shows that this group of heifers was hopelessly wrecked in the first breeding year, from which there was no recovery. During the four following years the 18 heifers with their female progeny of breeding age had dropped 33 per cent. Ideally the 18 heifers should have produced 27 female progeny from 1912 to 1914 inclusive which should have reached breeding age during, or before, 1916. The original heifers should have been in their prime and the total of females should have been 45, instead of 12—a deficit of 73.3 per cent. The ranks of the milking herd were being maintained by importation.

The owner pleaded financial inability to provide adequate housing and care for new-born calves. Five healthy heifers bred to a healthy bull would have produced more and better calves and milk during the period covered by the table than did the 18 physical wrecks. The economics of the subject may be variously interpreted but it would appear that it would have cost no more to have grown 5 healthy, than 18 diseased heifers. Later, the defects in calf growing were largely overcome, the mortality of calves much decreased and the abortion rate in first pregnancy dropped between 60 and 75 per cent.

Furthermore, the 18 heifers, as soon as recognizably pregnant, each received liberal amounts of killed abortion bacilli. At that date this was the most popular of the many panaceas for 'contagious abortion' and is still advocated by highly influential veterinarians. But it lamentably failed to overcome the handicap fastened upon them by disease as young calves—they had not so far recovered, although they appeared in splendid health, to be able to bear the burden of reproduction.

A second 'sure cure' for abortion is the inoculation of the animal with living abortion bacilli. While this group of heifers was not artificially inoculated with the living bacilli, a study of the table indicates that they acquired plenty of abortion bacilli, or something just as potent, to cause an appaling wreck. It may be objected that, under the prevailing theory, the 18 heifers acquired the infection after they had become pregnant and it would therefore *cause*, not *prevent* abortion in the first pregnancy. But the use of the living bacilli is based upon the allegation that one abortion tends significantly to render the animal immune to abortion thereafter. Of the 11 heifers which aborted in 1912 (one did not expel the dead fetus but was destroyed while in a dying condition because of the decomposing fetus), four (36.3%) did not again abort because they did not again become pregnant—they were permanently immune to abortion. A fifth heifer aborted the next year and then became incurably sterile and hence immune to abortion. The 11 heifers which aborted in 1912 produced during the next four years a total of 17 calves as compared with an ideal of 44—a deficit of 61 per cent. The 17 calves born comprised 6 heifers or an average of 1.5 heifer calves per annum from 11 heifers 'immunized' against "contagious

abortion' from having aborted. In this group of heifers, abortion as a sure cure for abortion has not proven a spectacular financial success.

A third great abortion remedy which has recently come into popular favor was applied to this group of heifers—they were strictly isolated from all other cattle from the time they were a day or two old until their first pregnancy had come to a close.

The breeder may *repent* his neglect of the health of his young calves, but nature will not *forgive* his sin. He must pay the penalty and pay it abundantly. He can not avoid the deluge by resort to isolation, by the giving of dead, sick or healthy abortion bacilli, by using Smith's abortion remedy, Jones' sure cure for sterility, or by resort to the century-old device of keeping a billy goat in the herd—he must pay the penalty. If he desires to escape these losses his path of safety lies in the direction of taking calves from healthy parents and carefully guarding their health in order to insure ample strength and resistance at breeding age that they may be able to carry the burden of reproduction with safety. The breeder has largely measured the sexual health of his cattle by their physical appearance and has been lamentably misled. Genital disease or defect, which has become established during life in the uterus or soon after birth, soon becomes glossed over by a faultless exterior which belies the state of the reproductive system.

Reproduction in domestic animals is properly a function belonging to the adult. Under forced feeding, the nutritive supply in excess of the requirements for growth, stimulates the premature advent of sexual life and causes heifers to come in heat, and renders pregnancy possible long before they have acquired the maturity and strength necessary to successful reproduction. Size does not constitute, alone, a dependable measure of the sexual strength of a heifer. In addition to growth, the heifer needs overcome, if possible, any infection or weakness in her genital organs which had become established during her life in the uterus of her mother or during early calfhood. Dairy heifers are largely bred at 15 months in order that they may calve—or abort—by the time they are two years old.

Abortion in dairy cattle is seen far more frequently during first pregnancy. Illustrating this fact, in a small herd observed over a period of ten years with 202 pregnancies and 30 abortions, the abortion rate in first pregnancy was 38 per cent, in second, 12 per cent and in third or later, 3 per cent. Exceptionally in dairy herds the abortion rate is highest in second pregnancy, and in beef herds this is a quite common experience. But in the beef herds the heifers are largely almost or quite a year older when first bred. In preceding paragraphs the frequency of abortion has been attributed largely to diseases of early calfhood from which the heifers had not fully recovered sexually. Inseparably related to this question is the age at which a heifer is bred. At what age may a heifer be safely asked to assume the load of reproduction? It may be reasonably believed that a heifer, or other young animal, supplied with an abundance of highly nutritious food and having excellent care in other respects, will be able to bear the load of reproduction safely at an earlier date than one having insufficient food. Whatever the character of disease may be, there exist, in the animal body, forces which constantly tend to overcome the malady and restore the individual to health.

This is apparently quite largely true of the diseases of calfhood which threaten reproduction later.

It would appear that a calf, which has suffered from disease imperilling future reproduction, would overcome such danger with increasing certainty as the time for such recovery is prolonged before asked to bear the burden of breeding. In beef cattle there is less haste in breeding heifers and the Hereford association bars early breeding. They apparently suffer less from abortion during first pregnancy. It would be unsafe to say that the difference is due to the age at which bred or to the fact that the Hereford calf is naturally grown, has enough, and rarely too much milk, and is, upon the average, far more healthy than the dairy calf. My belief is that both factors contribute importantly to the success. Apparently the Hereford breeder has concerned himself primarily with the effect of the date of breeding his heifers upon the ultimate size and quality of his cattle, and the dairyman has viewed the question from the standpoint of shortening the period between birth and lactation, associated with the idea that the earlier a heifer begins the secretion of milk, the more milk she will secrete. But the facts submitted in the preceding paragraphs supply grounds for the belief that the most important consideration in connection with the age at which a young animal is asked to breed, is the influence which it may exert upon the longevity of reproductive life, the regularity of reproduction, the quality of the progeny and, in dairy cattle, the total number of calves she will produce during her life and the average number of days she is kept from birth until death, for the production of a calf, because it is upon this latter consideration that her economic value must be based.

Abortion is the generally accepted index of breeding efficiency, but is inaccurate and misleading. When abortion is rampant in a herd, the breeding efficiency is admittedly low, but other factors in the long run play the chief rôle. Where I have been able to reach what seemed to me reliable estimates, sterility has caused at least ten times the loss that could properly be charged to abortion. Incurable sterility is the final breakdown in reproduction, but the great losses occur amongst animals which breed uncertainly after serious delay. Abortion is merely one symptom of sexual disease. Among the other manifestations of sexual disease are sterility, premature birth, difficult birth, retained afterbirth, diseased calves, and monsters.

Veterinarians and breeders have given far too little attention to the meaning of the duration of pregnancy, and have accepted as physiological for the cow anywhere from 240 to over 300 days, while for the mare they have regarded as normal any duration of time between about 310 and 400 days. The failure of the breeder to recognize the fundamental meaning of the duration of pregnancy as a reliable index to the sexual health of his breeding animals has robbed him of one of the most reliable sources of information at his command. The mare and cow abort with somewhat equal frequency. The cow shows a marked tendency toward premature birth; the mare an equally pronounced tendency toward prolonged pregnancy. On the contrary, prolonged pregnancy is rare in the cow; and premature birth perhaps even more rare in the mare. Careful studies of the matter indicate that the causes of premature birth in the cow, and of prolonged pregnancy in the mare, are essentially identical in their nature. The marked contrast

in result is perhaps due to wide differences in the fetal membranes, or afterbirths of the two species.

Von Oettingen, studying the meaning of the duration of pregnancy of mares in the famous Prussian stud at Trakehnen, states in his classic work on horsebreeding, that the foals born in that stud at 320 days or less largely developed into outstanding animals while those foaled at 345 or more days were almost never of great value. He presents much highly interesting evidence in support of his views, amongst which he shows that the great stallions of the stud were the products of short pregnancies. In my experience, foals carried grossly overtime are mostly small, sometimes dwarfs, and are frequently seriously or mortally ill at birth.

My studies of the afterbirths of mares show that, aside from rare exceptions of extensive disease, they are heaviest when the duration of pregnancy is not far from 330 to 335 days. Its weight consists, to the extent of 90 per cent, of the blood vessels through which the fetus gets its nutriment. It then follows that in case of a healthy uterus and a correspondingly healthy afterbirth, the vessels, the blood supply, reaches the maximum development, affords the highest available quantity and quality of nourishment, the fetus grows with the greatest rapidity and is born of largest size and greatest vigor. The breeder has long recognized the value of ample feeding of young animals but has overlooked the greater value of proper nutrition during that critical period of its life in the uterus. Of course he admits the value of feeding the pregnant female liberally but he fails to realize that the food may not reach the fetus. The food consumed by the pregnant animal can only reach the fetus in proper form and quality when the uterus is healthy, and in contact with it is a healthy afterbirth. The duration of pregnancy thus becomes a valuable index of the health of the organs through which the fetus is nourished, and hence of the health of the fetus itself. Hence if the duration of pregnancy falls below, or exceeds the ideal, it is evidence that disease or defect is present in the lining membrane of the uterus and in the external layer of the afterbirth of the fetus, the two structures constituting the placenta or organ of exchange of nutriment and waste products between the mother and her young. This disease or defect indicates that the breeder has imposed upon his animal the burden of reproduction when the genital system was not in a state of health to bear the load with safety.

According to my observations, prematurely born calves are poor prospects. They largely die. Many of those which survive are poor, or nonbreeders. There are notable exceptions. Some calves born very prematurely develop into good breeders. The low value has been most conspicuous in those calves born too weak to stand. It has been commonly advised that such weaklings be coddled but it would generally be better if they were killed.

In the ambulatory clinic of the New York Veterinary College for 1927-28, among 45 cases of difficult calving, 31 per cent was in two year old heifers. This marked prevalence of difficult calving in young heifers has commonly been attributed to too large a fetus or too small a genital passage. The calves of young heifers are almost invariably born after a shorter pregnancy than

in cows and are smaller in size than from adults. The genital canal is not markedly smaller than in the grown animal. But the tradition of too large calves, or too small genital passages in heifers has served as an opiate to the breeder and he sleepily accepts difficult calving of heifers as natural and inevitable. Modern clinical study indicates that it has a far more important meaning and that difficult calving is generally an indication of sexual disease.

Similarly, in the same clinic, among 114 retained afterbirths, 26.3 per cent occurred in two year old heifers. This can not be explained upon the theory of too large a fetus or too small a genital passage. It thus appears perfectly evident that in two year old heifers there is a marked excess of abortion, difficult calving and retained afterbirth. The breeder apparently places the burden of reproduction, which constitutes a full load for a healthy adult, upon an immature animal, often handicapped by disease established before birth or as a young calf, and she breaks down under the task. In contrast, a progressive Hereford breeder assures me that he regularly gets about 80 per cent of viable calves from his three year old heifers (first calving). His forage appears to be deficient in lime phosphate, and the heifer's reserve is heavily drawn upon during pregnancy and the demand is continued while the calf sucks. He wishes the heifer to calve again at four years old, in order to do which she must again be pregnant 80 days after calving, while the draft upon her store of lime phosphate is continued in order to furnish milk for the calf. For a period the heifer is asked to bear the double load of pregnancy and suckling a calf. She staggers under the load, chews bones, breaks down, and the second calf crop is very unsatisfactory. This breeder also observes that his outstanding show calves, which win blue ribbons at fairs and sell for high prices, are quite largely and conspicuously the progeny of cows which did not calve the previous year and thus enjoyed a long rest during which repairs were possible and nutritive reserves could be established. I have had an interesting discussion with him regarding the possible economy of witholding his three year olds from breeding, give them one year of rest from first calving, re-breed at four years, to calve at five years old, and then as an adult be able to produce a vigorous calf each year over a greater period of time than is possible under the present plan. Since his calf crop from his four year olds is not of great value under present conditions, the experiment should prove interesting and perhaps economically profitable.

The power of reproduction becomes established in the young of a given species at varying ages according to environment. A highly bred and fed heifer may conceive at five or six months of age if opportunity be given and a filly may become pregnant at ten or eleven months. With some notable exceptions, such early pregnancies are largely aborted or birth is premature and neither young nor parent is of great value. I recall clearly the experience of a client who carelessly permitted a yearling colt to run at pasture with a group of yearling fillies; almost all the fillies became pregnant and all that did so, aborted.

I believe the Hereford Association is correct when it bars the early breeding of heifers. Some dairymen claim that causing heifers to calve at two years old advances their dairying efficiency but it is not perfectly clear that in their calculations they have included the aborting heifers, the re-

tained afterbirths and other wrecks in their data, nor do they take into account the longevity of the cow with the total of calves and milk for her life. This feature is well illustrated by the Holstein cow, Glista Ernestine, bred and owned by the New York State College of Agriculture. She lived 5871 days and produced 13 living calves or one calf for each 451.6 days. She yielded for each day of her life 34.4 pounds of milk and 1.6 pounds butter. Her totals in calves, milk and butter were enormous and were made possible only by having lived more than sixteen years and having retained to the end her physical and sexual health and strength.

Animal husbandmen have too great a tendency to overload their young animals with a view to quick returns. They thereby secure deficient numbers of progeny, of inferior size and quality and far too often wreck, or seriously cripple, their breeding animals. Cattle and horses do not attain their maximum physical and sexual power until seven or eight years of age, by which time most breeding cattle have gone to the shambles, and the breeder has been deprived of the services of his breeding animals at that time during which they should produce the most vigorous and valuable offspring with the greatest regularity.

This leads to the question of the degree of sexual burden which the breeder may profitably impose upon his animals according to age or other factors which modify their strength. In some polygamous wild animals, such as the seal, and to some extent, some kinds of deer, the vigorous, adult males drive away the young and aged, so that only the most powerful males participate in reproduction. The cattle breeder quite commonly reverses this custom, ruins his young bull long before he reaches the natural age of highest reproductive power, and discards him. The exceptional bull which lives to make his mark as a sire is often loaded entirely beyond reason as old age comes on, staggers under the burden imposed, gets poor progeny and often seriously injures his cows.

There is an evil tradition that each mare and cow should produce young each year, and the dairyman thinks to increase the burden by having the cow furnish a generous quantity of milk for ten or eleven months annually. If a cow is pregnant for 285 days and it is desired that she calve again within 365 days, she must again become pregnant 80 days after having calved. In addition, the dairyman asks his cow to carry the further burden of heavy lactation during 70 per cent of the year. The question arises regarding the most prudent interval of rest between two pregnancies. In many cases, with mares and beef cows, it becomes desirable that young shall be produced at intervals of approximately 365 days, or in case of failure, that production be deferred for one year. As a rule, the interval between two pregnancies in dairy cows may be adjusted in harmony with economic needs, so that the double burden of pregnancy and lactation may be fitted to the strength of the individual. There is some degree of flexibility, also, in case of the mare and the beef cow. Breeding may be progressively deferred year after year until the season for giving birth may have become undesirably late, when one calendar year may be passed over. In his anxiety to have a cow produce a calf each 365 days the breeder too often breeds her 30 to 60 days after the termination of the last pregnancy, so that in case of failure, she may again be bred within the available interval of 80 days. He

thereby increases the danger of abortion, retained afterbirth and other results of sexual disease. In a group of 184 conceptions in dairy cows, 64 had become pregnant at less than 100 days after the termination of the previous pregnancy, of which less than 70 per cent produced healthy calves, while of the 121 cows which became pregnant 100 or more days after the previous pregnancy had come to an end, 83.5 per cent produced viable calves. The available data indicate that in the dairy cow, a second pregnancy, following the preceding one after an interval of less than 100 days, is far less safe than in those where a longer time has been allowed for repairs to, and readjustment of, the reproductive organs and adequate opportunity is given for the general recovery of vigor before resuming the burden of pregnancy.

The data available to me indicate that mares which conceive on the ninth day after foaling are approximately four times as likely to abort as those which become pregnant at a later date, but the tradition is so strong that the ninth day is the most favorable time for breeding mares, that many breeders would prefer to breed a mare at that time and have her abort, than to wait 30 days before breeding and get a healthy foal. In both mares and cows it is the most nearly healthy individuals which are competent to conceive early and yet these do not so well bear the load as the less healthy animals which conceive later.

A study of the sexual load imposed upon bulls is frequently highly interesting. In a large herd, two bulls of essentially the same age were used upon cows of presumably equal fertility over a period of ten years. The more popular one made a total of 691 copulations, the other, 213, or a ratio of 3:1. The former got twice as many heifer calves as the latter, instead of three times as many, as should have been anticipated. Following them into the next generation it was found that each had an equal number of granddaughters. The breeder looks forward to the influence of a great sire upon generation after generation but fails to appreciate fully the fact that sexual health also leaves visible traces over long periods. Some highly influential writers assert that a bull may advantageously serve 100 cows, and authentic records show that some bulls have greatly exceeded that number with success, but these have been exceptional bulls and do not constitute a safe standard for general custom.

In many cases no clear line of demarcation can be drawn between excessive sexual load and existing genital infection; the two factors are correlative. Hence in the above instance two interpretations are possible; it might be attributed to genital disease in the more heavily used bull, or to the weight of the sexual load, but the result is the same.

Table 3 illustrates strikingly the comparison between two bulls, the one healthy, the other clearly diseased as revealed by physical examination, both being used simultaneously in the same herd upon females presumably equally healthy. The diseased bull was technically fertile, but was obliged to copulate 2.3 times for each recognizable pregnancy, while the healthy bull copulated 1.5 times. The abortion and sterility combined amounted to 38.2 per cent for the diseased, as against 9.6 per cent for the healthy sire. The cows bred to healthy sire did not suffer from retained afterbirth or other inflammation of the uterus, whereas the diseased bull showed a total of 26.5 per cent with four fatalities.

TABLE 3. *Comparing the breeding histories of a sound, and an unsound bull in a purebred herd.*

	Calendar years	Number breeding years	Number copulations	Sterile		Aborted		Calves		Percent metritis		Average duration of gestation in days	Average copulations per pregnancy
				Number	Percent	Number	Percent	Number	Percent	Fatal	Non-fatal		
Healthy bull	1918-1920	62	82	5	8.0	1	1.6	56	90.3	0	0	285.0	1.5
Diseased bull	1919-1920	34	49	5	14.7	8	23.5	21	61.8	8.8	17.7	277.5	2.3

In another herd where seven bulls had each sired two or more calves, there is a striking correspondence between the number of services per live calf, the average duration of pregnancy for the living calves and the percentage of abortions, being as follows:

Bull No.	Aver. dur. of gestation	No. of calves	Services per calf	No. of abortions	Percentage of abortions
1	285	2	1.5	0	0
2	285	4	1.5	0	0
3	284.5	19	2.9	3	14
4	281.5	10	5.3	10	50
5	278.6	44	2.9	6	12
6	277.7	3	27.0	1	25
7	276.0	30	4.1	16	34.8

One of the most striking illustrations of the consequences of a sexual overload is seen in twin pregnancy in the mare and cow. Twin pregnancy in the mare almost invariably ends in disaster. Living twins are very rare, the physical life of the mare is in peril and her reproductive life is seriously impaired or destroyed. In single pregnancy, if the fetus dies or is seriously ill, the uterus commonly expels it—the mare aborts. But when twins are present one fetus often dies while the other remains comparatively well for a varying period. Conservative forces step in and the presence of the approximately healthy fetus restrains the uterus and the dead one is not expelled, but an attempt is made to continue the pregnancy on behalf of the living fetus. In the meantime the dead fetus undergoes changes and, in many cases, is largely absorbed by the blood of the mother and the uterus more or less damaged. Finally the disease overcomes the living fetus and the two are expelled, differing widely in the stage of development, as shown in Figure 2. This restraint exercised by the presence of a living fetus in the uterus is the saving element in swine, where regularly more than half the fertilized eggs in the uterus perish, are largely absorbed, and those which are not, are retained in the uterus so long as any living fetuses are present, and pregnancy continued to term when living and dead fetuses are expelled together. If the uterus of the sow emptied itself as soon as one fertilized egg dies, swine would become extinct.

Twins in mares frequently appear to be the result of sexual disease. In a badly diseased stud of thoroughbred mares with 26 pregnancies in one year, there were five twin pregnancies which ended as usual. Four of the five mares had been sterile over a discouragingly long period, and proved sterile again the following year. Three twin pregnancies are indicated in table 2, and in each case no calf was born during the preceding, or succeeding year. In the recorded data from another herd with three twin pregnancies, each cow died following calving or aborting or became incurably sterile. A cow reported by the Ontario Veterinary College, expelled ten fetuses in twenty months: two sets of twins, two of triplets, aborted in each case at three to four months.

There are some notable exceptions to the above. Some mares and cows apparently twin because of outstanding sexual strength and produce healthy and valuable young. As a rule twin pregnancy in both mare and cow con-

Figure 2. Aborted twin fetuses from a mare. The smaller fetus died at five or six months, the larger at about ten months. Had there been but a single fetus and it had died at five to six months, the uterus would have almost certainly expelled it at once, but the presence of the living fetus prevented. The uterus tried to nourish and develop a living fetus and at the same time dissolve and remove the body of the dead one. The uterus of the sow is capable of accomplishing this task and regularly does so.

stitutes an important peril to both fetus and mother. Twin calves are generally born at less than 280 days, are often very weak, defective in size, develop into poor breeders and the afterbirths of twin calves are largely retained. The ripening of two eggs at one heat in the mare and cow seems to be very largely due to a disturbance of the sexual system, in which case the original irregularity in the function of the uterus becomes aggravated by the presence of two or more fetuses when it is not in condition properly to nourish and develop one. Hence disaster should be expected.

Twins have attracted entirely too much sentiment and favorable attention. In the ewe, where twinning is comparatively common, the economic value has probably been greatly overdrawn by many. Even in the production of market lambs, some think it preferable that a ewe should drop a large, vigorous single lamb and nourish it abundantly, rather than bear twins of inferior size and strength which she can not nourish so well. At the same time the twin burden has a far greater peril for her breeding life and in the end she will probably produce no greater number of lambs during her life whether she bears twins or single lambs. Yet I have known a breeder to retain as a sire one of quadruplet lambs, apparently with the idea that he would thereby increase the breeding efficiency of his flock.

Any attempt to convert a uniparous, into a twin-bearing animal would appear to be a dangerous undertaking. The breeder may well hope, through intelligent study, to increase the size and quality of his animals materially, and by prudent care to prolong their efficiency over a greater period of time, but when he undertakes to change the zoölogical plan of reproduction he is treading dangerous ground. Years ago there was much chatter about a new breed of sheep which produced two lamb crops a year, but somehow the

noise concerning it has died down, and the old-fashioned ewe which came out of Noah's Ark and regularly produces one healthy lamb per year, still seems satisfactory to many sheep breeders, apparently because she is constructed upon a plan which enables her to produce one valuable lamb once a year and to keep it up over a maximum number of years. The ewe which was to produce two lamp crops per year is reminicent of another breed of sheep announced at about the same time, which would defend themselves against dogs, and might even kill the dog if they got him cornered, but the losses of dogs from having been killed by sheep has not yet caused great anxiety to dog fanciers. The ewe, with a normal duration of pregnancy of five months, and producing one lamb a year, enjoys a rest period of seven months between pregnancies, and she responds by producing the most nearly ideal number of young observed among domestic animals.

The effects of the burden of reproduction are shown in a variety of ways, so that by careful observation the breeder may determine the extent of the load which an individual may safely and profitably carry. In addition to those already discussed, two highly important means have recently been placed upon a secure basis for measuring sexual health and strength: the stained spermatozoa of the male and the afterbirth of the female.

In the past, aside from the breeding record itself, the male has been judged by his sexual behavior, the presence or absence of obvious sexual disease, by the motility of freshly discharged spermatozoa and the duration of their motility. While these are of distinct value, it has now been clearly established that by a microscopic study of stained spermatozoa, there is revealed through their size, form and other characteristics, accurate information of the utmost value to the breeder, far excelling all other sources of evidence combined. Its chief point of superiority over all other available means is the fact that it makes possible the determination of the degree of fertility after a single copulation, without awaiting the result of the service and in the absence of any physically recognizable disease of the sexual organs. The outstanding value of this means lies in the fact that the state of sexual health and strength may be determined in advance, before the sire shall have had the opportunity to wreck the herd. Technically, if a male causes some of his females to become evidently pregnant, regardless of the number of services required, he is fertile, and as commonly viewed, safe. The fact is that the male which is absolutely sterile is commonly devoid of danger except for a brief delay. It is the male which is capable of impregnating some of his females which is the great peril in the herd. The sire is one half the breeding unit and his sexual health is of equal importance to that of the entire group of females. As shown in table 3 the sexually diseased bull establishes pregnancies which are unsafe, some are aborted, in others birth is premature, retained afterbirth is common and death of the females not rare. In such case the motile spermatozoa are present and pregnancy follows copulation in many cases. The usual means for determining the efficiency and safety of the male are not operative until, if dangerously diseased, he has wrecked the herd. A proper examination of the stained spermatozoa often prevents the disaster. No other test of equal value is known. This is well illustrated by spermatozoa from two stallions shown in Figures 3, 4 and

5. Figure 3 shows the spermatozoa of a highly fertile thoroughbred stallion. The sperm cells are essentially uniform in size and contour. Figures 4 and 5 illustrate the spermatozoa from a stallion of extremely low fertility. Most mares served by him were later sterile when bred to healthy stallions. The spermatozoa are few and are extremely variable in size and form.

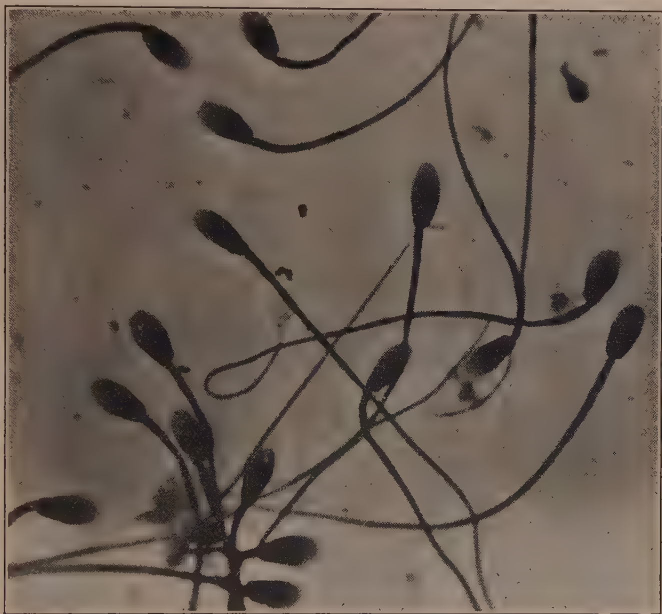

Figure 3. Spermatozoa from a highly fertile stallion. The sperms are quite uniform in size and form.

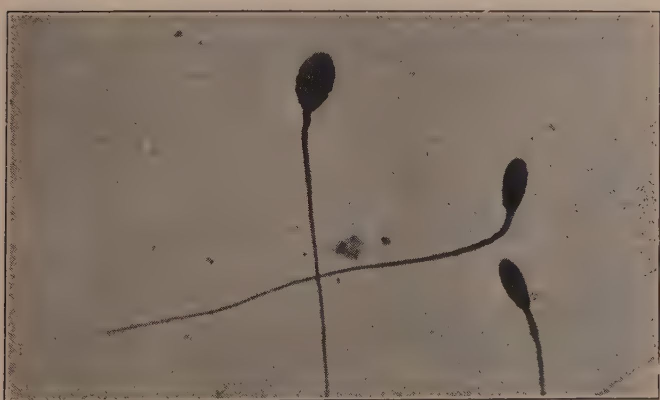

Figure 4

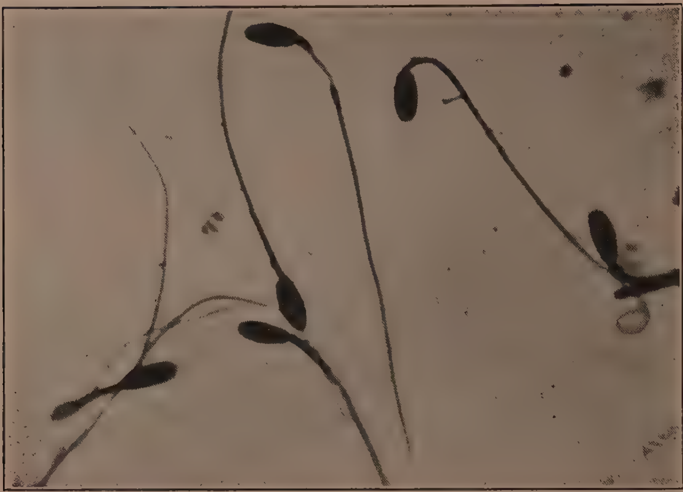

Figure 5

Figures 4 and 5. Spermatozoa of a stallion of extremely low fertility. He so damaged his mares that most of them would not conceive later when bred to healthy stallions. The sperm cells are irregular in size and contour and show effects of disease.

The study of the afterbirth constitutes the most reliable measure known for determining the ability of a female for carrying the burden of reproduction. It is limited to those females which have been pregnant and from which the afterbirth has been obtained. It has been studied most in the cow. It has the special virtue that, with proper study and diligence, the breeder may himself determine the facts in his own herd. When a heifer calf is born there are present and clearly evident four well developed parallel ridges in the lining membrane of the uterus which extend from end to end of the organ. There are also two rudimentary ridges, not usually so well developed. Upon these ridges the cotyledons or 'buttons' of the uterus are developed in four regular rows, with occasional supplementary cotyledons upon the two rudimentary ridges. The total varies, usually between 100 and 110. The cotyledons constitute the physiological contact between the afterbirth of the fetus and the uterus of the cow, by means of which the fetus obtains its nourishment. Once destroyed, they are not reformed, and once damaged, they are not ideally repaired. New structures are sometimes developed in the presence of disease of the regular cotyledons, but the adventitious formations are frail structures of low efficiency in supplying nutriment to the fetus and in guarding it against disease. The arrangement of the cotyledons in the heifer calf is shown in Figure 6. The numbers and fundamental arrangement of these remain constant throughout life except that some, many or all of them may be destroyed and not replaced.

Pregnancy produces important changes in size and in their finer structure, and the growth of the uterus separates them farther from each other. The cotyledons or 'buttons' of the afterbirth, which are an essential part of the fetus, are a precise copy of those of the uterus. The arrangement of the cotyledons in the pregnant uterus is well shown in Figure 7, from a heifer pregnant 90 to 100 days.

Figure 6. Uteruses from veal heifers five to ten weeks old. The horns of the uterus have been dissected apart, opened along their convex border and laid out flat to show the cotyledons or 'buttons'. 1. The vagina; 2, the neck of the uterus; 3, the right horn; 4, the ovary.

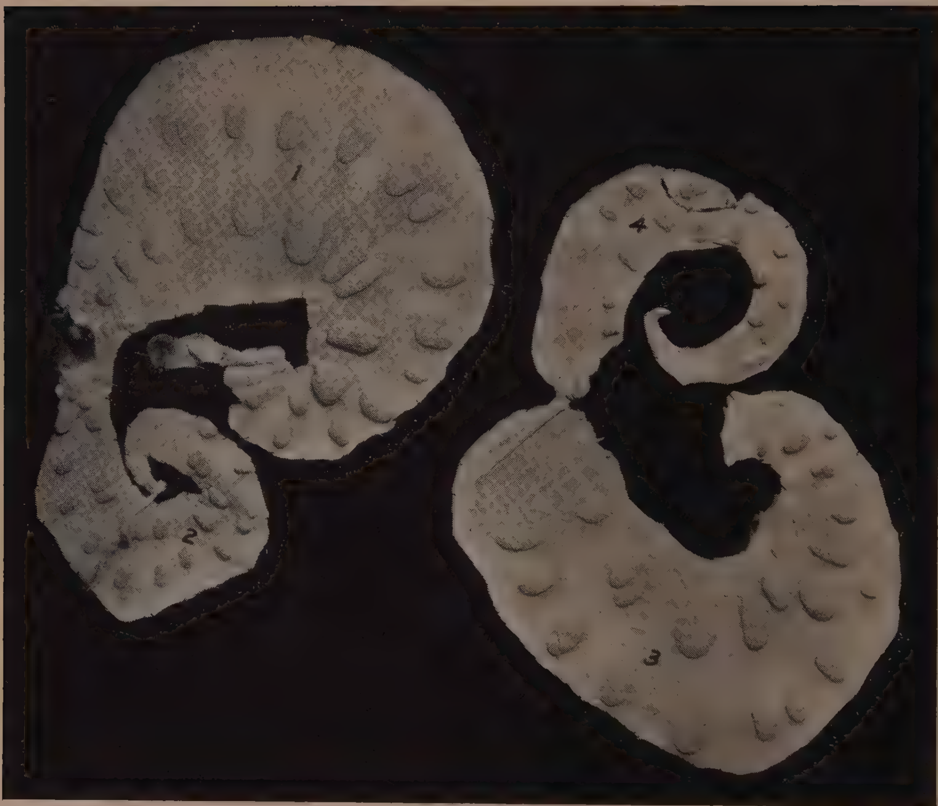

Figure 7. Uterus from a heifer pregnant 90 to 100 days. The horns have been dissected apart as in previous case, and the entire organ divided along its middle into two halves, so they could be spread out flat and expose the four parallel rows of cotyledons. 1 and 2, the lateral, or outer side of the pregnant and non-pregnant horns respectively; 3 and 4, the median or inner sides of the two horns.

Figure 8 shows the afterbirth of a young cow with excellent breeding record. She was twice served by the bull, she bore two vigorous calves, one pregnancy of 286 days, the other of 283 days, she calved without aid and expelled afterbirth without delay. The photograph shows the normal cotyledons, symmetrically arranged in four parallel rows. The only criticism is that in the non-pregnant horn a few small adventitious structures (placental growths) have occurred, presumably due to slight irritation. The breeder may safely conclude that bred to a reasonably sound bull and kept in average general health she may confidently be expected to continue her record—one healthy calf for each copulation, the duration of pregnancy to average 285 days, the calving to be without aid and the afterbirth to come away promptly.

Figure 8. Afterbirth from a young cow of excellent breeding history. 1. The ovarian end of the pregnant horn; 2, the navel; 3, the part lying between the navel and the neck or mouth of uterus; 4, the cervix or neck at point where membranes ruptured for escape of calf; 5, the non-pregnant horn. It has been cut almost in two in order to double it back to bring it in the camera field. It shows a few adventitous growths (small, dark elevations) referable to slight irritation of the uterus at some previous time.

Figure 9 furnishes a sharp contrast. The photograph is of a specimen obtained from slaughter house, pregnant 150 to 180 days. As a consequence of a former pregnancy, all the cotyledons in one horn of the uterus, and for a considerable distance in the other horn were destroyed and with these the mucous membrane itself was destroyed to a degree that it could no longer act in nourishing a fetus. More than two thirds of the area physiologically concerned in the development of the fetus have been utterly destroyed. Such injury is not rare after severe retained afterbirth and occurs when a fetus dies and decomposes in the uterus. The cow was presumably sent to slaughter because of her bad breeding record. How many times she was bred before conception can not be guessed. One third of the uterus was forced to bear the load of pregnancy for 150 to 180 days, but as pregnancy advances the load increases and it may be seriously doubted if pregnancy could have been safely completed—I have not seen, nor known of a case where such a uterus succeeded.

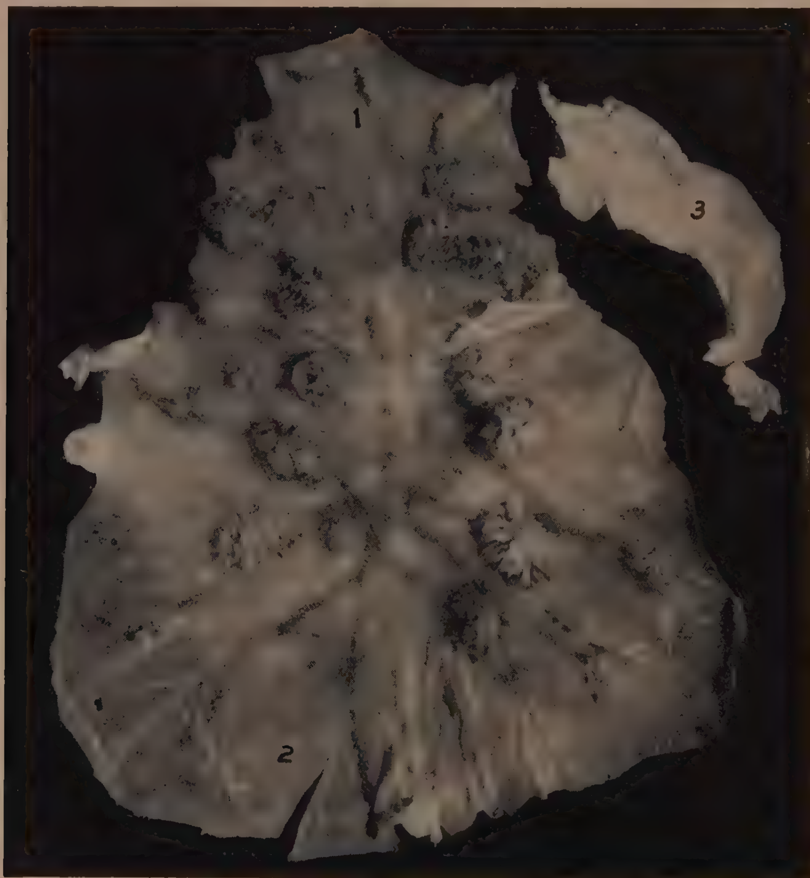

Figure 9. Afterbirth from a slaughter house cow, pregnant 150 to 180 days. The mucous membrane or lining membrane had been completely destroyed in some prior pregnancy, in what is now the non-pregnant horn. 1, The ovarian end of the pregnant horn; 2, the cervical, or neck end of the pregnant horn. A large area at this end is very thin, without prominent blood vessels and has no cotyledons. Like the non-pregnant horn, the lining membrane of the uterus had been destroyed in connection with a prior pregnancy; 3, the non-pregnant horn of uterus, into which the afterbirth did not extend.

Figure 10 represents the afterbirth from the second calf of an unhealthy cow. Born February 10, 1924, she was served many times, exact number not determinable, and finally calved after a pregnancy of 287 days, when 1237 days old (3.4 years). She was then bred five times and calved at 287 days on March 27, 1929, when 1827 days (5 yrs., 45 days) old. The two calvings were 635 days apart and she had produced one calf for each 936 days of her life. Her blood reacted to the agglutination test at various periods at from 1:160 to 1:320. The figure shows that at the ovarian end of the non-pregnant horn, 1, the cotyledons have been destroyed. At the cervix, 2, just opposite the 'mouth' of the uterus, at the point where the afterbirth ruptured to permit the exit of the calf, the cotyledons have been destroyed and in their stead, diseased new formations have been produced, black from the large amount of old (dead) blood in them. The cotyledons or 'buttons' in the pregnant horn are somewhat deficient in number. The fine tufts, villi or delicate hair-like prolongations upon the surface of the cotyledons have been extensively damaged by disease, many of them destroyed, and those remaining, in an attempt to compensate for the damage, have grown to excessive size and are extremely coarse, like those shown at 2 and 3 in Figure 11. The cow has not aborted; she has not been observed to expel a dead fetus. The disease changes suggest that very young embryos had died, decomposed, and after injuring the uterus, were broken up and absorbed or were expelled unseen, in either case constituting sterility.

The contrast between a healthy, and a diseased uterus is well shown in the more detailed Figures 11 and 12. In Figure 11 are shown one cotyledon from a healthy uterus, and two from a diseased one. The healthy cotyledon, 1, is from a cow born June 1, 1923. She dropped her first calf February 20, 1926 (2 yrs., 7 2-3 mos.). While her service record is not available, she apparently conceived promptly. Bred June 6, 1926, she calved at 287 days on March 20, 1927. At about this date the agglutination test for 'contagious abortion' was begun, her blood being positive at 1:640, and has continued positive at high titre. Bred June 27, 1927, a rest interval of 99 days, she aborted twins at 232 days. After a rest interval of 125 days, she was bred on June 19, and again on July 1, 1928, and calved at 290 days on April 17, 1929, from which calving the cotyledon illustrated was obtained. For her last three conceptions—the data for her first conception not being available—she had four services or 1⅓ copulations per pregnancy. There is something irregular concerning her services on June 19 and July 1, with a heat interval of but 12 days. Possibly there was an error concerning her being in heat on June 19, with a forced service. The abortion of twins is a common phenomenon. The afterbirth indicated with much force that the abortion was not accompanied by any extensive or important damage to the uterus.

The other two cotyledons, 2 and 3, in Figure 11 were obtained from a cow in the same herd. She was purchased in Wisconsin in September, 1927, ostensibly after a negative agglutination test, and has remained negative. She calved (from Wisconsin breeding) November 19, 1927, was bred 74 days later, on February 1, 1928, again bred March 10 (interval of 37 days), then on April 4 (25 days), April 26 (22 days), May 28 (32 days) and July 15 (48 days). There had been a total delay in conception of 164

Figure 10. Afterbirth from an unsound uterus and poor breeding cow. 1. Ovarian end of non-pregnant horn. That portion of the uterus had suffered from serious disease in a prior pregnancy, the cotyledons of the uterus had been destroyed beyond repair, no cotyledons could form on afterbirth in this area; 2, the cervical or neck area, thickly covered by dark-colored adventitious growths; 3, navel.

Figure 11. A cotyledon, 1, from a sexually healthy, and two cotyledons, 2 and 3, from a diseased uterus.

1. An ideally healthy cotyledon or 'button' with uniform, closely packed velvety villi or tufts; 2, a small cotyledon, in which disease has recently destroyed almost all the villi. Some of them are matted together by blood clots; 3, a gigantic cotyledon from same afterbirth. It has been badly damaged in a prior pregnancy, many of the crypts or cavities in the surface of the cotyledons of the uterus being destroyed by disease. The remaining crypts became enlarged and irregular, and the villi or hair-like prolongations upon the afterbirth became overgrown and coarse. This gives to the cotyledon a very coarse, clumpy character.

days, with six services, with no two equal intervals in heat periods. Perhaps several embryos perished in the diseased uterus and were absorbed. She finally calved at 278 days, seven days short of the ideal proposed above.

The non-pregnant horn of the afterbirth was long, narrow, very thin and without cotyledons. In the pregnant horn the cotyledons were about normal in number but gigantic in size, as may be seen by comparing 1 and 3, in Figure 11. The villi, or delicate projections from the surface of the cotyledons, which extend into corresponding depressions in the cotyledons of the uterus, and constitute the essential area of contact between the fetus and mother, have been largely destroyed, and compensation has been attempt-

ed by gigantic size in those remaining. So nature has done her best to compensate for the destruction of half the uterine cotyledons by gigantic growth of the other half, and to compensate for the loss of many of the depressions in the remaining cotyledons by giantism of those remaining. It reminds one of a badly cracked wagon tongue, covered with a promiscuous collection of old boards, tied on with hay wire—it may hold together. While the healthy cotyledon, 1, has less than half the gross superficial area of the damaged one, 3, the fineness and numbers of the villi give it probably two or three times the contact area of the other. It has a far greater power for supplying nutriment to the fetus and for guarding its health. It is infinitely more capable of sustaining the burden of reproduction.

The comparison between healthy and damaged uterus is further emphasized in Figure 12, in which magnified portions of 1 and 3, in Figure 11 are placed side by side.

The changes caused by disease of the uterus are faithfully recorded in the afterbirth, so that a careful study of the latter reveals the past sexual history of the female and affords a reliable index by which the breeder may measure the ability of the cow to bear the burden of reproduction. In the cases used as illustrations the agglutination test for Bang's bacillus has been positive alike in the badly wrecked uterus with bad breeding history and in the ideal uterus, with perfect breeding history; cows with badly diseased uteruses with corresponding bad breeding histories have been negative to the test. But after a careful study of more than 400 uteruses and afterbirths at Cornell University, those of us who have participated in the work have found that where the breeding history is available, it checks accurately and reliably with the condition of the afterbirth.

In the case of Glista Ernestine, previously mentioned, the afterbirth from her thirteenth calf clearly showed that she still had a remarkably healthy uterus. She was a great cow and had a great uterus. *No cow can be great without a healthy uterus.* With a healthy uterus a cow may successfully overcome important barriers. At the zenith of her career, the blood of Glista Ernestine was positive at 1:500 to the agglutination test for 'contagious abortion' but with a healthy uterus, that mattered little.

The outstanding value of the examination of the afterbirth, as I see it, lies in the fact that any intelligent breeder may examine the evidence for himself and, with experience, reach a reliable conclusion. The process of examination is not profoundly difficult, but requires careful work*.

The chief aim of this address is to stimulate original observation and thought by the breeder. He is not asked to accept the conclusions offered, or even the statements presented, as facts. It is hoped that some will take sufficient note of the statements to lead them to compare the ideas presented with the occurrences within their own herds.

At present the whole breeding world is in a mad panic over 'contagious abortion', the basis for which lies back over thirty years—almost as long as the Israelites were held in the wilderness—and the anxiety constantly grows.

*Following the address, the method of examination of the afterbirth of mares and cows was demonstrated by Professor Williams with material provided by Professor J. M. Brown, an account of which will be found on page 190 of this issue.—Editor.

Figure 12. Magnified areas from cotyledons 1 and 3, of Figure 11, placed side by side to emphasize the contrast between the diseased and healthy structures.

During this long period the breeders' attention has been directed almost wholly to extrinsic matters. He has looked for help to influential leaders in veterinary science and bacteriology, and has done very little to help himself through careful observation and study of matters which lie open immediately before his eyes and are preëminently his own affair. He has kept his eyes riveted upon his neighbor whose herd, he fearfully suspects, harbors 'contagious abortion' and failed to study the facts in his own herd with a view to correcting vital errors in his methods of breeding and care. He has failed, it seems to me, effectively to weigh the sexual burdens he has imposed upon his animals or to measure their ability to carry the load demanded. A ton truck may carry two tons at a low speed over a smooth road not too long, and a breeding animal may carry an unnatural and imprudent sexual burden for a while, but each is in constant peril of a breakdown. The breeder, when the disaster comes, calls it 'contagious abortion' and curses his neighbor for sending him the dread infection.

External dangers should not be ignored. No breeder is justified in purchasing a sexually unsound animal and placing it in his herd. But it is of infinitely greater importance to the intelligent breeder that he study the conditions in his own herd in an effort to advance to the utmost the general, and sexual health of his animals, and to adjust the burden of reproduction to the capacity of his animals to carry it. These things lie well within his jurisdiction and constitute the basis for success. Sexual health is just as essential as pedigree. The animal which has been wrecked sexually can not produce either a satisfactory number or quality of young. Shielding them against 'contagious abortion' or other fancied or actual infection from without can not correct the defects within.

DEMONSTRATION OF A METHOD FOR EXAMINING THE AFTERBIRTHS OF COWS

W. L. Williams

The demonstration was a continuation of the address earlier in the day, "The Burden of Reproduction", and was designed to emphasize to the breeder the value of a study of afterbirths as a means of enabling him to estimate the reproductive strength of females. In the address it had been claimed that a proper examination of the afterbirth afforded the most reliable method available for this purpose.

For the demonstration there were provided a number of pregnant uteruses from the abattoir, one recent afterbirth from a fresh cow and one from a mare which had just foaled.

In the abattoir material a series of four cases were arranged, the uteruses opened and the afterbirths, surrounding the fetuses, exposed.

1. A fetus of between 8 and 9 months. The cotyledons or 'buttons' were regularly arranged in four parallel rows and were symmetrical in size and form. The areas between the cotyledons were smooth, clean and free from any adventitious or disease growths. The body of the fetus was unstained and clean, amniotic fluid clear and virtually colorless.

There are two fluids partially, or wholly surrounding the fetus, the amniotic and allantoic. The former immediately surrounds the fetus and into it opens the digestive apparatus both by mouth and anus. In healthy fetuses,

however, the contents of the bowels are not emptied into this sac: both fluids are clear. But in disease of the fetus or its afterbirth, the contents of the bowels are emptied into the inner sac.

2. A uterus containing a fetus of about eight months. The cotyledons were not so regular as in the preceding, and the surface of the afterbirth between the cotyledons showed signs of disease in the form of adventitious growths, due apparently to irritation,—probably bacterial. The amniotic fluid, in which the fetus lay, contained many pellets of meconium, fetal feces, or excrement. The fetus had been sick and, as in the new born calf, the disease had expressed itself by abnormal action of the bowels. It was not diarrhoea as generally understood, the meconium being in hard pellets, smaller than normal. They had been unnaturally expelled as a result of disease. The fetus constantly swallows its amniotic fluid and incidentally portions of any excrement mixed with the fluid.

3. A uterus containing a fetus of about six months. Its afterbirth was definitely diseased. The cotyledons were irregular and some were missing. The intervals between the cotyledons showed many new placental growths. The amniotic fluid had a greenish-brown, dirty appearance and many small brown flakes floating in it. The almost hairless skin was smeared over with masses of feces, showing that the fetus had had definite diarrhoea. This condition is often observed in fetuses at any time after they have reached a length of 12 to 15 inches when the afterbirth shows much marks of disease as seen in this case. Apparently the diarrhoea is due to the disease of the afterbirth, at least when the afterbirth is so diseased a large proportion of fetuses have diarrhoea. The disease of the afterbirth seen in this case dates back to a prior pregnancy which had damaged the uterus and lowered its power to bear the burden of pregnancy. As a result of its weakened state, the uterus was unable to control the activities of bacteria commonly present; the latter multiplied, attacked the afterbirth and fetus and caused disease. Had the cow been permitted to live, abortion would have been probable. The fore legs of the fetus were contracted.

4. A uterus containing a fetus of about 7½ months. The afterbirth in the non-pregnant horn of the uterus had no cotyledons but was thickly covered over with adventitious growths, very bloody and showing appearances of disease. In the pregnant horn the afterbirth and uterus showed some rather poor cotyledons and many adventitious placental growths, like those in the non-pregnant horn. The uterus had evidently been seriously diseased in a prior pregnancy, probably from abortion or retained afterbirth or both, and had suffered destruction of all cotyledons in the non-pregnant horn (perhaps in that pregnancy it was the pregnant horn). The mucous membrane of the uterus had been so damaged that extensive areas of new growths subsequently developed.

The amniotic fluid of this fetus was dirty brown and turbid. It contained flakes of meconium or feces. The fetus had suffered severely from diarrhoea and, had the cow lived, abortion would have been highly probable. Such a cow is a failure as a breeder. She conceives tardily after several or many services and then quite certainly aborts or calves prematurely. In the latter case the calf is inclined to be weak and to suffer from diarrhoea (calf scours) and finally to be of low value in case of survival.

The character of the above material suggested very strongly that the cows in question were sold out of diseased herds because they were poor breeders owing to genital disease.

5. An afterbirth from a dairy cow which had just calved. As usual it had been trampled in bedding and dung, and afforded a good opportunity for demonstrating the proper method of examining such material. The afterbirth was spread out upon a table and washed by means of a slow stream of water (without pressure) from a stable hose. When cleansed and carefully laid out flat, the sac was divided with scissors, along its middle line, opposite to the course of the main arteries and veins. The membrane was then spread out completely in a single layer. The cotyledons were carefully cleansed under a gentle stream of water and the fine villi or tufts, mometarily submerged, floated to and fro. Their details were thus brought out clearly. The cotyledons were excellent. All parts were normal, giving good indication that the cow was both sexually healthy and an excellent breeder.

6. The afterbirth of a mare which had foaled a few hours previously. The duration of pregnancy was 348 days as compared with an ideal of about 334. The afterbirth weighed 6 lbs. 14 oz. as compared with an average of 10 to 12 lbs. It was opened in a similar manner to the preceding, and spread out flat on a table. Under a slow stream of water it was clearly shown that in several areas of ¼ to 1 sq. inch the villi or tufts had become diseased and destroyed. One area was covered by a yellowish, white mass of pus, others by old dark-colored scabs, and in yet other areas the scabs had fallen away and the resulting naked areas had healed. Here it was shown that the abnormal prolongation of pregnancy, the deficient weight of the afterbirth and its disease were parallel. The evidence indicated that the uterus was below the ideal in health, that as a consequence the growth of the fetus was tardy, the afterbirth too small to provide ample nutrition, and, as a partial compensation, the fetus was retained over time in an effort to complete its development. This state of low sexual health suggests delay in rebreeding in order to give the uterus ample time for repairs before again assuming the burden of reproduction.

On the whole it was attempted to demonstrate that to attain the most satisfactory development and to complete such development in 285 days in the cow and 334 in the mare, the afterbirth needs be healthy. Finally the demonstration was designed to be in harmony with the prior address, and to show that if the breeder desires to grow healthy, vigorous progeny, it is important that he shall plan to see that the fetus shall have abundant nourishment of high quality during the period of gestation. The breeder should clearly understand that feeding the pregnant female is not necessarily feeding the fetus in like degree. The female must first digest and assimilate her food but after that it must yet reach the fetus in proper amount and free from injurious substances, in order to do which the uterus and the afterbirth must both be healthy.

In the main address it was stated that one of the important marks of healthy reproduction is that the young are born unstained by feces. In these cases it was shown that disease of the fetus is common.

A GENETIC CONCEPTION OF HARDINESS *

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The more recent literature on the general question of hardiness presents the results of research upon many phases of the problem. Some of the findings bid fair to stand the test of time as our knowledge of this subject is being built up. In spite of all of the investigations, however, the fruit grower knows that his plants are still injured by low temperature. Neither from the applied nor the scientific standpoint, therefore, can the problem of hardiness be considered solved. What, then, are some of the main features of hardiness as we see the problem now?

In the first place, we must keep in mind that in the world exchange of crops many species and varieties have been taken to places to which they are not adapted. This is the fundamental fact back of the hardiness problem and has been from the beginning of our attempts to move fruit bearing plants away from their native habitat. By contrast, take note of the way the native trees "come through" the winters as compared with some of the introduced forms, in spite of all of the protection and care given to the latter.

Types of injury: Let us note briefly, at the outset, some of the types of injury to fruit plants from low temperatures. This phase of hardiness has been covered in considerable detail by horticulturists (*1, 2, 3, 4, 5, 6, 7*, etc.) and, consequently, needs only brief mention here. At one extreme there is killing outright of the entire plant even by mild winters. At the other are the hardy forms which are not injured by the severest winters. The latter category may include introduced varieties which have been taken to a region not materially different from the native habitat of the species. Between these extremes there is tip killing, twig or branch killing, killing of the top to the snow line or to the ground, and, finally, root injury or root killing.

In fact, one of the interesting features of "winter killing" is the localization of the injury. Potter (*5*) found injury to appear first as "a browning of the immature xylem cells, just within the cambium layer," with "immature phloem cells just outside the cambium" next in order, followed by wood rays, cambium, phloem and cortex. Roberts (*8*), following the suggestion of Sorauer (*9*) but working with the sour cherry, thought that the hardiest cells were those in which the protoplasm was dense and in which vacuoles had not as yet developed. In the plum (*6*) the pith area below the flower buds often shows injury when other parts of the fruit or flower bud do not. It is not unusual to find one or more flower buds in a fruit bud killed while others are apparently uninjured. The localization of injury is further shown by the greater killing of fruit buds in certain locations on the twig. The bud scales of the fruit bud may also be killed while the flower buds escape injury. At the Minnesota Station, in *Prunus davidiana*, the fruit buds were all killed year after year, while the leaf buds were seldom injured so that growth was affected.

In many instances the terminal twigs are more severely injured than the older branches. Still other types of injury are referred to as crotch injury,

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bark splitting, sun-scald, crown injury, and wood and bark browning. Another phase of the localization of injury in fruit plantings is found in differences in exposure, elevation, or protection. These instances will suffice to show some of the variables in the expression of injury from low temperatures.

Physiology of hardiness: In view of the fact that the killing point of most plants rises to near 32°F. or even above during the growing season, and drops to well below sero F. during dormancy, it is obvious that fundamental changes take place within the plant with the approach of winter to make this adjustment possible. Furthermore, since this adjustment must of necessity take place at the end of each growing season, it is expected that there would be irregularities because of so many variables arising from differences in the soil, moisture supply, temperature, cultivation, fruit production, or length of season.

The end result of all of the internal changes taking place in the fall is usually referred to as maturity. Other things being equal, this is probably the most important consideration in hardiness. After the tissues have matured, the next important consideration is the rest period. As used in this connection, the rest period refers to that part of the dormant period when a given species cannot be induced to grow even if conditions are suitable. What is gained in temperature endurance, by maturity, must, therefore, be maintained and continued by rather profound rest or inactivity. When the rest period is broken, the killing point begins to rise. As, with the approach of maturity, the killing point drops gradually, so, during the break in the rest period, it rises again.

The details of the complicated changes which take place with maturity are not well understood. In some instances, as with seeds, there is a great reduction in water content. This factor alone, however, does not seem to be so important in woody tissues where the water content does not vary greatly between the winter and summer condition. Succulent tissues can be "hardened off" by growing at a lower temperature. This may be one item to be considered in woody plants also, since growth generally ends during the falling temperatures of late fall. The greater susceptibility of late growth in such fruits as the peach, raspberry, grape, or plum to winter injury gives some indication of how necessary it is to modify the cultural treatment in those regions where low temperatures are encountered.

Within the cell there could be marked changes in the protoplasm without the tissue as a whole showing a great reduction in water content. Since increasing the quantity of materials in solution increases the resistance to low temperatures, a concentration of the cell sap is undoubtedly of consequence in bringing about hardiness. This is one important means of adjustment when plants are subjected to low temperatures because ice crystals seem to form in the intercellular spaces rather than within the cells. Muller-Thurgau (*10*), for instance, thought that at -20°F. 75 per cent of the water in oak twigs was in the form of ice. In this same connection it is interesting to note that at -21°F. the plum fruit bud is packed with ice between the scales but that none is found immediately adjacent to the young flower buds, in the area enclosed by the bud scales (*6*).

Many suggestions appear in the literature on hardiness as to the changes which take place in protoplasm with the oncoming of temperature endurance. Hydrophyllic colloidal substances are undoubtedly increased. These increase

the water holding capacity of the protoplasm and lower the freezing point. Chandler (*11*) states that the most plausible explanation of the "protective effect of very stable colloidal substances" is that they increase the stability of the protoplasm against "irreversible changes." This view is supported by the fact that both rapid freezing and rapid thawing may cause injury. In view of the extent of the withdrawal of water from the cell by low temperatures, the theory of Gorke (*12*) that death may result from the concentration of the sap, or that of Muller-Thurgau that death from freezing is due to the rapid loss of water from the protoplasm, thus causing a disarrangement of its components, appears plausible. Cytological studies of winter killed cells in the flower bud of the plum (*6*) show that "the peripheral regions of the cells are delimited by an irregular margin that stains very heavily" and that there is a broken down appearance to the nucleus. This condition within the cell indicates that with killing there is a profound disturbance in the cell organization.

The rest period: The fact that all parts of a plant are not injured alike by low temperatures or that injury under similar conditions may be different in severity is ample evidence that there are many variables in winter injury. The rate of freezing or thawing (*5, 6, 11, 13*), the duration of the exposure to low temperatures, the maturity of the plant, and the time of year, all appear to have a bearing upon the extent of injury. In addition to these, greater emphasis is now being placed upon the rest period. This phase of the subject will not be discussed at length at this time. However, the extremely short rest period of some of our fruit crops, such as the peach (*14*), or the relatively early break in it, as in the plum (*6*)—even under conditions characteristic of the Minnesota winters—illustrate the intimate connection between the killing point and the rest period.

The fact that roots do not appear to have a rest period is of particular significance in this connection. Instances have been noted where nursery stock in transit has been severely injured by temperatures only slightly below the freezing point. The experiments of Carrick (*15*) show the marked changes in root hardiness during the dormant season. In the more severe climates the danger in this direction is appreciated. At the Minnesota Station the writer found a soil temperature of 9°F. six inches deep under a snow protection when the air reading had been as low as -21°F. Under such conditions differential killing is sometimes encountered between the roots of the scion and stock and conditions are approached where even the hardiest roots may be subject to injury. It would seem that in crop improvement experiments the rest period of the varieties selected as parents should be constantly kept in mind in breeding investigations.

In the discussion above, an attempt has been made to sketch some of the outstanding features of the horticultural and physiological phases of hardiness. Those familiar with the literature of the subject will appreciate how much has been omitted in attempting to keep within the limits of this discussion. As horticulturists and fruit breeders, interested in the improvement of our variety list in a broad way, we are confronted with this question: Does hardiness come within the realm of genetics? That is, is hardiness, as we know it, something which can only be built up physiologically within the plant or is there something inherent in the germplasm which can be transmitted like other plant characters?

Adaptation and hardiness: In the discussion of this phase of hardiness let us first examine our present conception of a species. Emphasis need not be given here to a historical treatment of the "species concept." Even if species be regarded as "judgments," there are in nature fairly distinct entities which can in many—perhaps most—cases be regarded as quite different in important particulars. Recent thought recognizes sub-species, physiological races, saltations, mutations, bud variation, in addition to such variations as giant forms, weeping types, a deeper fruit color, weeping and cut leaved varieties, or in rare instances, individuals lacking pubescence or even chlorophyll. To make matters even more complicated, the geneticist has gone counter to apparently natural tendencies and has made numerous interspecific combinations. The multitude of variables from these combinations in horticulture alone is bewildering. But in this background let us not lose sight of hardiness. Let us note first some illustrations of the problem involved in moving plants of a species from one point to another within the limits of the native habitat.

Oak seedlings were grown at Itasca Park in Minnesota, by Professor J. P. Wentling, from acorns collected from native trees in Clarian County, Pennsylvania and from University Farm and Itasca Park in Minnesota. In this instance we are moving individual plants northward within the native range of the species (*16*). "The first year after planting all of these seedlings made a good growth. During the following winter those from Pennsylvania were killed outright, top and roots. Those from University Farm were killed back to the snow line, while those from Itasca Park were not injured at all."

Let us take another instance, this time of plants moved from the northern part of their range to the southward. In the summer of 1916 the writer collected open-pollinated seed from wild plants of *Rubus strigosus* east of Winnipeg, northward from this point on Lake Winnipeg at Little Bull Head, Big Bull Head on the west shore, and at Big George Island still farther north toward Norway House. Seed was then obtained in the Riding Mountains at Dauphin and McCreary, northwest of Winnipeg. The farthest point to the south at which seeds were collected in this instance was at Baudette in northern Minnesota. Plants from these different seed sources were grown in the test plots at the Minnesota Station for four years. During the winter of 1919-20 there was extensive killing back of these seedlings but an occasional plant from the Baudette seed grew from the terminal buds. In 1920-21, however, there was an "open winter" and the canes of all of these seedlings were killed to the ground, the killing taking place before February. In the spring all plants grew again from the roots, so that there was not complete killing.

Let us take still another instance, one in which plants from the northern and southern range of the species are brought together toward the central part of the area of natural distribution (*17*). The native range of *Vitis vulpina* extends from the Gulf of Mexico to the Lake of the Woods, and Lake Winnipeg. In the spring of 1913 three eye cuttings were obtained from Fayetteville, Arkansas; Columbia, Missouri; Ames, Iowa; St. Anthony Park, Lake Itasca, and the Lake of the Woods, in Minnesota. In March when letters were sent out for cuttings to the south the plants were growing in Mississippi and Louisiana, so that plants were not obtained from these sources. These cuttings were placed in the same cold frame at the Fruit

Breeding Farm, 20 miles west of Minneapolis. The point that is interesting about these grapes in this connection is that a frost on October 10, 1916, killed the leaves on the cuttings from Iowa and Arkansas, without injuring the leaves on the plants from either of the three points in Minnesota.

In this same connection it will be interesting to note the effect the winter temperatures of 1919-20 had upon 117 self-pollinated seedlings of the Gregg raspberry growing at the Fruit Breeding Farm in Minnesota. In a progeny of 117 plants twelve were killed completely, 33 were killed to the ground, 17 were killed back half way to the ground, while 55 grew from the last bud left when pruned. The last two groups may have been put together, but it is probable that in the last one there were some plants which would have grown from the terminal buds. Unfortunately, there were no plants of this variety growing outside for comparison.

Differential killing in seedlings comparable to these instances has been reported by a number of investigators *(3, 5, 15, 18, 19, etc.)*. A striking case of variation in the hardiness in seedlings was observed at Vincennes, Indiana, the past season in one-year-old Mazzard cherry nursery plants, of which only about 10 per cent in a plot of considerable size survived the winter exposures.

The significant point in these illustrations is that fundamental differences were encountered in the cold resistance of plants belonging to a given species, but coming from different points in the natural range of distribution. Similar differences in hardiness in the Gregg raspberry and Mazzard cherry seedlings, also determined by natural winter exposures, give a narrower view of such differences in hardiness. The inference from the genetic standpoint is that these differences observed are genetic in origin and that as far as temperature endurance is concerned the plants of a species from the northern and southern part of the natural range are genetically different.

The explanation is that natural selection, acting through a long period of time upon forms heterozygous for those factors which determine temperature endurance, has built up types toward the northern and southern part of the range of the species which are genetically different. It is conceivable that at the northern and southern range of widely distributed species there is an approach to homozygosity for the characteristics necessary to endure either heat or cold.

The inheritance of hardiness: Let us now turn to the breeding plots and see how hardiness behaves in inheritance. In order to be brief, only a few illustrations will be chosen from the studies on the inheritance of hardiness in the plum, which were made at the Minnesota Experiment Station *(19)*. While recognizing the short-comings of field tests of this kind, nevertheless, the experiments were carried out under conditions comparable to those confronted by the fruit grower.

In investigations of this kind it has been customary to use a hardy form as one parent, with some compromise in hardiness in the other parent, provided other desirable characteristics were present. It is possible, therefore, with hardiness as a variable or a limiting factor, to make combinations of parents with many degrees of hardiness involved. For instance, we can arbitrarily group the varieties of a given fruit into three classes: hardy, intermediate, and tender forms. A parent variety could be selected

from any one of these groups and crossed with a parent possessing the degree of hardiness characteristic of each class. It would be possible, therefore, to make nine different combinations as to hardiness within these provisional classes. In table 1, only three of the possible relationships of the parents as to hardiness are included. These crosses illustrate the general trend of the response of plum seedlings to winter exposures and illustrate some of the extremes in hardiness or injury encountered in the different progenies.

TABLE 1. *An illustration of the inheritance of hardiness in plum crosses where the parents possess different degrees of cold resistance. The different individuals of these progenies are classified according to the degree of injury during the test winter of 1917-18. The first cross was selected to illustrate a hardy × hardy combination, the second a tender × hardy, and the third a half-hardy × tender.**

	Number of trees planted	Number killed before 1917.	Dwarfs—Less than 3 ft. high.	Trees severely injured 1917-18: Killed top and root	Trees severely injured 1917-18: Killed to ground.	Trees severely injured 1917-18: Killed to snow.	Trees examined in more detail.	Classification of trees which survived the winter of 1917-18 — Killing back of twigs: Two feet or more.	Killing back of twigs: Average of 1 foot.	Killing back of twigs: Average of 6 inches.	Killing back of twigs: Average of 2 inches.	Killing back of twigs: Tip or terminal bud	Killing back of twigs: No injury.	Bearing no flower buds.	Percentage of flower buds killed: 100 per cent.	95 per cent.	75 per cent.	50 per cent.	25 per cent.	10 per cent.	5 per cent.	No injury.
Zekanta × *P. americana*	20	1	–	–	–	–	19	–	–	–	–	13	6	2	–	–	–	–	–	–	–	17
Burbank × DeSoto	44	21	5	–	–	–	18	–	–	–	2	4	12	6	–	–	–	1	1	2	2	6
Wakapa × *P. pissardi*	70	17	7	20	13	8	5	–	1	–	1	3	–	1	–	1	2	1		–	–	–

*Taken from Technical Bulletin 32 of the Minnesota Agricultural Experiment Station.

"From the applied standpoint, it is important to know when a hardy variety is crossed with a tender one, whether the F_1 will all be hardy, all tender, all intermediate, or whether all degrees of hardiness between the parents will be encountered." The Minnesota experiments show, in general, "that where hardiness is present in both parents, the progeny are hardy; where both parents are tender, the progeny are tender; and that where extremes are encountered in the hardiness of the parents, gradations in hardiness occur in the progeny, although the intermediate individuals are not typically represented as would be expected in an uninterrupted series of multiple factors." The differences in hardiness between the seedlings in the different progenies in the test plots were of the same nature apparently as those observed in the oak seedlings or the red raspberry. While the plum breeding experiments did not furnish evidence as to the probable number of factors for hardiness in this material, it would seem safe to assume that within a progeny there is a difference in the genetic constitution between one plant which grows from the tip buds of the terminal shoots after a severe winter and one which was killed to the ground or killed outright. As far as survival values are concerned, a "test winter" would have much the same effect in eliminating the tender individuals in a progeny of plum seedlings under test as in a "clump" in the wild. We have in the "test winter," therefore, an illustration of

the operation of natural selection with material heterozygous for hardiness.

From this brief survey of the hardiness problem, it would seem that we may well feel encouraged over the progress which has been made even though we have as yet only partly met the situation for the fruit grower. We have tested our varieties and species after sufficient time has taken place in the world exchange of crops to enable us to have some assurance as to the completeness of the job and the soundness of the results. The physiological studies have shown us much of the way in which plants withstand low temperatures and, from these studies, we may confidently look for tests which will give an accurate index of the hardiness of those seedlings which are named and propagated. The bearing of maturity and the rest period upon hardiness is now appreciated and the variety tests upon a broad scale have given us an understanding of our fruit list in these respects. The recognition of differences in hardiness between individuals or varieties within the species has given a conception of the problem involved in selecting hardy parents. The inheritance studies show that hardiness is of such a nature that it can be dealt with in the breeding plot much the same as other quantitative characters and that we also have a genetic approach to this problem. Finally, when we take a long look at our variety recommendations and take stock of the shortcomings of even our best varieties as we see them growing in the orchard, we must admit that the task of fruit improvement is only begun.

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A STUDY OF THE COMPARATIVE MORPHOLOGY OF THE SEEDS OF AGROPYRON*

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SPECIES OF *Agropyron* REFERRED TO IN THIS PAPER

A. repens, (L) Beauv.
A. Smithii, Rydb.
A. tenerum, Vasey.
A. caninum, Beauv.
A. Richardsonii, Schrad.
A. divergens, Nees.
A. dasystachyum (Hook) Scribn.
A. cristatum, Beauv.
A. violaceum, Vasey.
A. alaskanum, Scribner and Smith.
A. acadiense, Hubbard.
A. albicans, Scribn. and Smith.
A. inerme, Scribn. and Smith, (Rydb.)
A. elongatum, Host.

A. biflorum, (Brignoli) R. and S. is synonymous with *A. violaceum.*
A. spicatum, Scribn. and Smith, and *A. occidentale,* Scribn., are synonymous with *A. Smithii.*

The opening up of a new country creates new problems. In the early days of farming in Western Canada the wild grasses of the prairies provided the necessary hay and pasturage, especially as only a small amount of live stock was kept on the average farm. As the country developed, more pasture land was plowed up and the amount of stock increased; thus it became necessary to seed down land to cultivated grasses and clovers. There were many cultivated grasses to choose from, but only five or six of them were suited to western conditions.

It was natural that some enterprising farmer should try some of the wild grasses under cultivation. Among the most promising of them were those belonging to the genus *Agropyron*, the Wheat-grasses. The first record we have is that in 1885 a Mr. McIvor of Virden, Manitoba, grew Slender Wheat Grass, *A. tenerum* Vasey. At about the same time this grass was tested by Dr. R. Bedford, then Superintendent of the Brandon Experimental Farm, who expressed the view that it was one of the best grasses for cultivation in the west. It was erroneously called Western Rye Grass and this name supplanted the right name—Slender Wheat Grass. Now the former has become so commonly used that no attempt is being made to change it. It is a tufted or bunch grass and is, therefore, better suited for the production of hay than pasture. When used for hay it gives a large yield per acre and, if cut before it becomes too mature, makes hay of first-class quality.

Another grass, Awnless Brome, *Bromus inermis*, Leyss., was brought from Russia and, as it thrives in dry districts, it is well suited to the southern portions of Manitoba and Saskatchewan where the other grasses give poor results. It has a large root system which enables it to resist drought.

However, the introduction of these two grasses was not an unmixed blessing. One of the worst weeds of Europe is Couch Grass, *Agropyron repens* (L) Beauv. It travels under many aliases, all modifications of one another—Couch, Cooch, Quack, Twitch, Wick, Wickens, Twickens, and others. It is a serious pest because it spreads by underground root-stocks

*A thesis submitted to the University of Manitoba in partial fulfilment of the requirements for the degree of Master of Science.
†Supervising Analyst.

in the same way as Sow Thistle and thus, when once it gets a start, it is difficult to eradicate. It was introduced from Europe into eastern Canada and the United States. There, although one of the worst weeds, it was quite different from the other weeds and the crops in the vicinity, and thus it stood out from them and could be combatted by itself. As far as I can determine, it is not native in western Canada but has been introduced there as an impurity in the seed‡ of Brome Grass. After its arrival, the question of its eradication became acute. In addition to *A. repens* and *A. tenerum*, the genus *Agropyron* contains about sixty species of which fifteen to twenty are present on the western prairies. Couch Grass and Western Rye Grass can be distinguished by the fact that, whereas the former has running root-stocks, Western Rye Grass has not. However, some of the wild *Agropyron* possess running root-stocks, e.g. Western Wheat Grass, or, as some of the farmers call it, Western Couch Grass or Blue Stem. The name Blue Stem should be avoided as it is applied to at least half a dozen different weeds.

The seeds of Agropyron species are so similar that not only cannot the seeds of one species be cleaned out of those of another species, but they cannot be told apart except under a microscope or other magnifier. Accordingly, from a seed stand-point, the situation resolves itself into this: Couch Grass seed cannot be cleaned out of the seed of Brome or Western Rye Grass, and the farmer or seed merchant cannot tell whether or not he has any Couch Grass seed in his Western Rye Grass seed or even whether it is Couch Grass or Western Rye Grass seed that he sees as an impurity in his Brome.

In the Seeds Act, 1923, of the Dominion of Canada, Couch Grass was listed as a primary noxious weed. However, no one on the staff of the Seed Branch or at the Agricultural Colleges was prepared to distinguish between the seeds of *A. repens, A. tenerum, A. Smithii,* Rydb., and the many other species of *Agropyron* prevalent in western Canada and as yet unstudied. While one might be able to distinguish samples of seed of these grasses from one another, the identification of an individual seed of *A. repens* in a sample of Brome or Western Rye Grass seemed so difficult that the seed-houses claimed that it could not be done. The result was that in eastern Canada, where probably 99 per cent of the *Agropyron* found as an impurity in seed is *A. repens,* all *Agropyron* seeds were recorded in seed analyses as Couch Grass, and in western Canada they were reported as Western Rye Grass which in the west is the most common impurity. Accordingly, in 1924, the Advisory Seed Board removed *A. repens* from the noxious list. The result was a clamour from the farmers who wisely insisted that it was one of the worst, if not the worst, of our weeds. In 1925 it was put back on the noxious list, this time as secondary noxious. It became imperative that the Winnipeg Seed Laboratory should learn to distinguish the seeds of *Agropyron* species from one another.

The literature on the seeds of *Agropyron* was meagre and did not treat of the many species common to the western prairies. Dr. J. H. Hillman had published a bulletin entitled *The Distinguishing Characters of the Seed of Quack Grass and of certain Wheat-grasses* (2), based largely on

‡The word "seed" in this paper is used in a popular sense and refers to the ripened floret.

studies of the spikelets and the outer glumes rather than on the individual seeds. Dahlberg's paper, called *Identification of the Seeds of Species of Agropyyron* (*1*), was more comprehensive. A paper published privately by Sarvis called *Suggestions for the Identification of the 'Seeds' of Quack Grass (Agropyron repens (L) Beauv.), Western Wheat Grass (Agropyron Smithii Rydb.), and Slender Wheat Grass (Agropyron tenerum Vasey)* (*5*) dealt with the pubescence of the palea and the rachilla. However, all these publications treated of *A. repens, A. tenerum* and *A. Smithii* only, and within these species there seemed to be much variation not taken into account by these authors *.

I was sent by our Canadian Department to Washington, D.C., to study with Dr. F. H. Hillman of the United States Department of Agriculture; but all that he and I could do there was to examine carefully a few authentic samples of *A. tenerum, A. repens* and *A. Smithii.* Accordingly, I spent most of my time with Dr. Hillman in studying species of *Agrostis* and other grasses, and I returned to Winnipeg to examine under the microscope all specimens of all species of *Agropyron* that I could obtain. I worked over the plants in the herbarium at the Manitoba Agricultural College, but many of these were still unnamed. The University of Saskatchewan had lost its herbarium in the fire which destroyed the Field Husbandry building, but Professor Kirk supplied me with samples of the different strains of *A. tenerum* under investigation in his experimental plots together with *A. elongatum* and *A. cristatum.* All *Agropyron* found in seed samples coming into the Winnipeg Seed Laboratory were studied under the microscope and reported as (1) Couch Grass, (2) Western Rye Grass, (3) Western Wheat Grass, or (4) other Agropyron. As some fourteen species and varieties appeared which could not be identified, I adopted numbers as a temporary basis for my records, and these numbers are used in this paper.

The *Agropyron* No. 1 form differed from the others in possessing marked indentation on the dorsal side of the lemma on each side of the rachilla (see Plate 1.). Experience has shown that this is an evidence of immaturity only and that it occurs in all species. Although *Agropyron* No. 1 is not referred to again in this paper I have mentioned it here, as the indentations have confused other workers and are likely to again.

Analyses of grass-seed samples made from July 1, 1925, to July 1, 1926, are given in table 1.

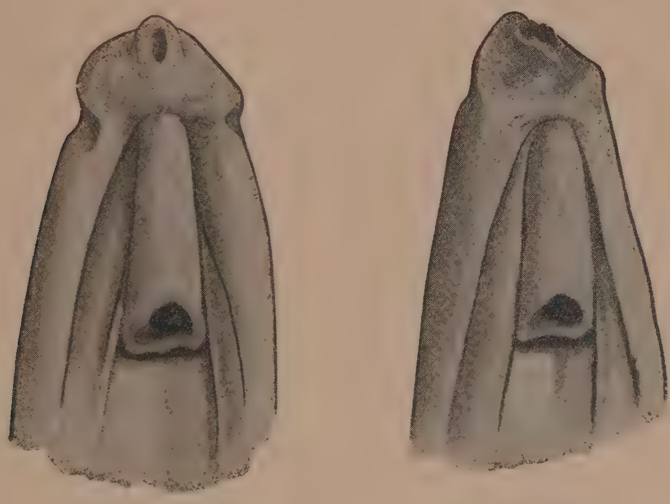
In the summer of 1926, the Canadian Department made it possible for me to study the genus *Agropyron* at the National Herbarium and the strains of *A. tenerum* under investigation at the Central Experimental Farm, Ottawa. Acknowledgment should be made here to Dr. M. O. Malte and Dr. G. P. McRostie for placing material at my disposal and for assisting me. Most of the strains at the Central Experimental Farm had been collected by Dr. Malte. At the National Herbarium I was able to study the morphological characters of the following fourteen species: *A. tenerum, A.*

*Since this paper was read before the Western Canadian Society of Agronomy, in December 1927, a paper by H. Henry called "The Seeds of Quack Grass and certain Wheat Grasses Compared" has come to hand. This is the best paper on the subject hitherto published. It contains some excellent drawings.

TABLE 1.—*Analyses of grass seed containing Agropyron made at Winnipeg Seed Laboratory for one year* 1925-1926.

	Brome	Western Rye Grass	Mixtures containing Western Rye Grass
Number of samples	453	168	54
Number of samples with *Agropyron*	422	168	54
Number of samples with *A. repens.*	208 (46 per cent.)	14 (8 per cent.)	10* (18 per cent.)
Number of samples with *A. tenerum.*			
A. No. 2 type	3	—	—
A. No. 3 type	19	—	1
A. No. 5 type	114	68	18
A. No. 9 type	60	—	4
A. No. 12 type	393	168	54
Number of samples with *A. Smithii,*			
A. No. 6 type	91	1	—
A. No. 7 type	61	1	3
Number of samples with *A. dasystachyum*			
A. No. 4 type	18	3	—
A. No. 10 type	19	—	—

*All ten samples contained Brome as an ingredient.



Immature seed showing indentation

Mature seed.

PLATE I.

caninum, A. Richardsonii, A. repens, A. Smithii, A. divergens, A. dasystachyum, A. spicatum, A. biflorum, A. violaceum, A. inerme, A. acadiense, A. alaskanum and *A. albicans.* The commoner species of *Agropyron* may be grouped as follows:

(1) *A. repens group*: awned and unawned forms,

(2) *A. tenerum group*: *A. tenerum* (A. No. 12—apparently the commonest form), *A. Richardsonii* (A. No. 9), *A. caninum, A. inerme,* and my forms A. No. 5 and A. No. 11.

(3) *A. Smithii group*: A. No. 7, a form with a hairy palea, and A. No. 6, a form with a glabrous palea.

(4) *A. dasystachyum group*: A. No. 4, a form very hairy over the entire seed, and A. No. 10, a less hairy form.

From observations made at the National Herbarium and the Central Experimental Farm it would appear that the forms or subspecies just given are distinct and breed true, and that each of them produces seeds of one form only. This will be discussed more fully later.

During the winter of 1926-1927 most of my time was spent on the routine identification of Agropyron found in samples coming into the Winnipeg Seed Laboratory. The results were similar to those obtained in the previous year and, for the commoner forms, are given in table 2.

TABLE 2.—*Analyses of grass seed containing Agropyron made at Winnipeg Seed Laboratory for one year*, 1926-1927.

	Brome	Western Rye Grass	Mixtures containing Western Rye Grass
Number of samples	331	123	45
Number of samples with *Agropyron*	314*	123	45
Number of samples with *A. repens*	146 (44 per cent)	2 (2 per cent)	4 (8 per cent)
Number of samples with *A. tenerum*	293	123	45
Number of samples with *A. Smithii*	95	1	1
Number of samples with *other Agropyron*	11	3	—

*Only seventeen samples were free from Agropyron.

As it was evident that approximately half of these stocks of Brome seed examined in 1925-1927 contained seed of Couch Grass and that the latter could not be cleaned out of the former, it was necessary to encourage the farmers to produce Brome seed free from Couch Grass seed. In 1926, Mr. J. E. Blakeman, District Seed Inspector, offered to inspect fields of this crop just before cutting time and, if no seed of Couch Grass were found in the standing crop or the threshed seed, to seal the bags of seed with a certificate enclosed to that effect. A few farmers took advantage of the offer and as a result, four hundred acres around Graysville (Manitoba) were inspected. In 1927, the demand, not only from Graysville but also from other points, mainly in southeastern Saskatchewan, was so great that over four thousand acres were inspected. Three interesting facts were revealed by this field inspection:

(1) The most important fact was that the living plants in the field bore out in detail the identifications already made from the study of morphological characters of herbarium specimens.

(2) Formerly, to distinguish the plants of *Agropyron,* inspectors looked for the type of head, the habit of growth, and, if they suspected *A. Smithii* or *A. repens,* the presence or absence of running root-stocks, which necessitated digging. Having learned to distinguish the plants by their seed with a hand lens, we abandoned the old method and proceeded as follows: we snatched off any head that we thought should be identified, tore open the spikelet, which, as it opened, showed the lemma of one seed and the rachilla and palea of the next seed, examined the appearance of these organs with

a hand lens and thus made our identification. The new procedure was not only more accurate than the old but saved much time.
(3) Approximately half the fields passed the inspection test and half failed—a result in harmony with that given by two years' analyses of samples of seed.

Routine analyses of a large number of samples have since afforded further opportunity for study. The seed-houses have sent many samples to the Winnipeg Seed Laboratory and one well-known firm has made its buying contracts with the growers of Brome seed subject to the stock being pronounced free from the seed of Couch Grass, by this Laboratory. Samples of seed from practically all the fields passed as free from Couch Grass in 1927 have been tested, many of them several times, for grower, seedsman, and coöperative cleaning plant. Analyses of these have borne out very closely the findings obtained by field inspection.

A new development of the problem has arisen with the experiments which are being made by the Field Husbandry Departments of the University of Manitoba and the University of Saskatchewan with *Agropyron cristatum* as a forage crop. It is understood from these sources that this grass is quite promising and that seed of it will enter the commercial trade shortly. This introduction will complicate matters, not only because it will present another European species to be confused with the present common ones but because this seed more closely resembles the seed of *A. repens* than do any of the others of this genus. While one might readily distinguish samples of seed of these grasses from one another, one individual seed of *A. cristatum* and a small rolled seed of *A. repens* are so similar as to offer difficulty in identification.

Some Distinguishing Characters of the Seeds of Certain Species of Agropyron

Maturity—Bromus inermis, Agropyron tenerum, and *A. repens* mature about the same time, namely, the last week of July and the first week of August. *A. Smithii* apparently is one to two weeks later, as it was in the early flower stage when Brome and Western Rye Grass crops were field inspected, just prior to cutting. Thus the majority of the seed of *A. Smithii* found in stocks of Brome and Western Rye Grass is immature and, because of that, is greener in colour, softer in texture, and cannot be reported in seed analyses as an impurity. *A. divergens* is later still, flowering in August and ripening seed from September to frost (*4*). This probably explains why the seed of the species is only rarely found as an impurity in our Brome and Western Rye Grass seed.

Character of Spikelets:—Hillman (*2*) in comparing *A. repens, A. tenerum*, and *A. Smithii*, says: "Owing to the close relationship of these grasses, their seeds, taken individually at least, appear to be practically indistinguishable. The structure and fruiting habits of seed clusters, however, afford means for their recognition which appear to be well founded." The spikelet consists of several alternately arranged ripened florets or "seeds" between and partially above two oppositely placed slender scales or glumes. These glumes are united on the same level, which fact is an excellent distinguishing character for spikelets of *Agropyron*. From Hillman's des-

cription of the three commonest species the following tabulation may be made:

TABLE 3.—*Comparison of glumes of three species of Agropyron.*

A. repens	*A. tenerum*	*A. Smithii*
½—¾ inch long	½—¾ inch long	¾—1 inch long
Glumes diverge slightly or maybe nearly parallel.	Glumes commonly nearly parallel, tip curving inwards over the seeds.	Glumes more divergent, exposing the lower seeds.
Seeds extend beyond glumes from slightly to ½ length of glumes.	Seeds do not extend beyond the glumes or do so by not more than ⅓ latter's length.	Seeds extend beyond the glumes by latter's length.
Glumes 5 to 7 veined, veins distinct, the central prominent, giving the glume a keeled form.	Glumes 5 to 7 veined, veins slender and central vein not more distinct than others. Glume rounded at the back.	Glumes 3 to 5 veins, mid vein somewhat coarser, giving glume slightly keeled form.
Mature spikelets tend to retain individual seeds and consequently spikelets always appear with comparatively few free seeds in samples containing Couch Grass.	Mature spikelets break apart readily.	Mature spikelets break apart readily.

I have checked these descriptions in field and laboratory and have found them to hold with the exception of the last. While more mature spikelets retain their seeds in *A. repens* than in *A. tenerum* and *A. Smithii*, not over twenty-five per cent. of the seeds of this grass are present in commercial samples in spikelet form. Also, most of the *A. Smithii* and other native species in seed stocks are immature and consequently still in spikelets rather than as free seeds. Furthermore, many samples of Brome contain seeds of three or more species of *Agropyron* and, accordingly, it would be inaccurate to classify all as *Agropyron repens, A. tenerum* or *A. Smithii* because a few spikelets had been identified as belonging to that species. To sum up, the above descriptions are valuable in identifying individual spikelets present, but this solves only a small part of the problem. Dr. Hillman's paper was published in 1911 and he has done much further work on *Agropyron* since then.

General Shape.—All *Agropyron* seeds are roughly boat-shaped but the seeds of two species differ somewhat from the others. Seeds of *Agropyron divergens* possess an awn which diverges from the lemma at a marked slant. This twists the lemma out of position and exposes the palea to a greater degree than is the case in the other species (see Plates II and III). Many seeds of *A. tenerum* are unsymmetrical (see Plates IV and V), due to the spikelet being closely appressed to the rachis; whereas the palea, attached to the rigid grain, remains normal in shape, the lemma conforms to pressure. Seeds of *A. cristatum* and of most forms of *A. dasystachyum* are smaller than those of other species. Seeds of *A. cristatum* are wide at or near the base in proportion to their length; the lemma and the palea are markedly inrolled.

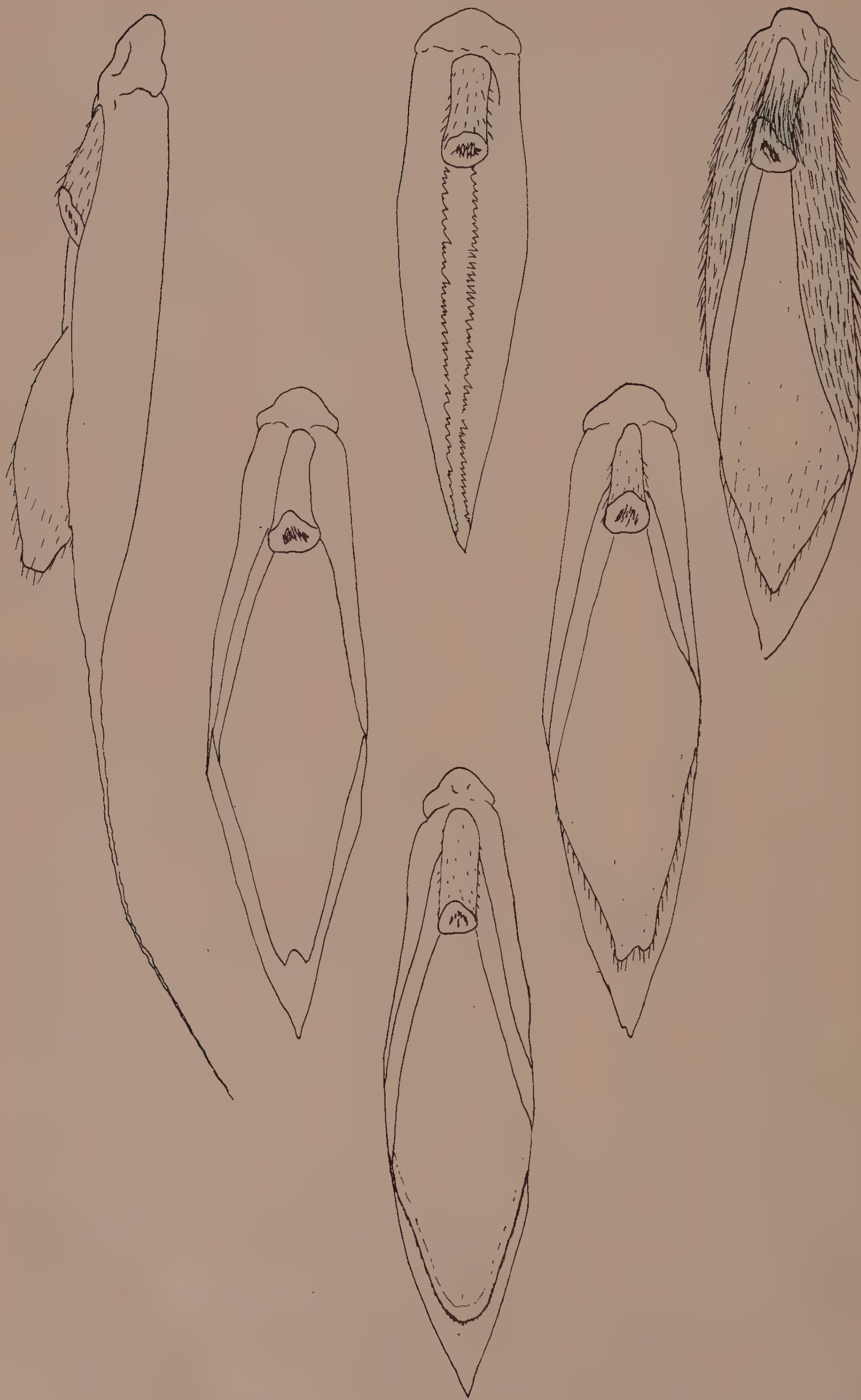
Colour and Texture.—Seeds of all species of *Agropyron* are yellow in colour; if immature, they are greenish yellow. Mature seeds of *A. tenerum*, of *A. caninum*, of *A. Richardsonii*, (including the variant forms of these three species) and of *A. cristatum* are a light yellow. Those of *A. Smithii*, of *A. dasystachyum* and of *A. divergens* are a deeper yellow. However, seeds of *A. Smithii* found in samples of commercial seed are usually greenish because of their immaturity. Mature seeds of *A. repens* are a rich golden yellow with almost a brownish cast. The seeds of this species, also, possess a lustre and their glumes are thicker than those of the seeds of other species. The palea and the lemma of *A. Smithii* are thin enough to show the grain dark underneath.

Lemma—The most important parts of the lemma are the callus, the hairs, the nerves and the awn. The term callus signifies that portion at the base of the lemma where the seed is attached to the rachilla of the next seed. (In this paper I will refer only to the ventral half of the callus). This part of the seed is very distinctive. In *A. repens* it stands out as a delineated section, is free from hairs, and is shiny. In *A. Smithii* there are hairs on the sides of the callus, also extending up along the sides of the lemma, but there are no hairs on the centre of the callus. In *A. tenerum* and its closely allied forms, *A. caninum*, *A. Richardsonii*, A. No. 5, A. No. 11, etc., and in *A. dasystachyum* and in *A. divergens* there is a fringe of hairs extending right across the callus. There are so few and such fine hairs on the callus of the seeds of A. No. 5 that it is difficult to see them even under a miscroscope unless one has the seed turned with its base away from him, in order to get the best reflection of light by the hairs. However, in the seeds of this species the callus is never shiny nor is it as clearly delineated as in the seeds of *A. repens*. The seeds of *A. tenerum* (A. No. 12) have longer hairs on the callus than those of A. No. 5; A. No. 12-a and *A. caninum* have longer than A. No. 12; and A. No. 11 have very straight, fairly long, hairs (equal to A. No. 12-a) which project straight up the lemma. *A. Richardsonii* has very long hairs which project out like an untrimmed moustache.

The portion of the lemma immediately above the callus is characteristic. Mature seeds of *A. repens* possess a marked hump at this point, whereas seeds of *A. Smithii* have a definite depression. Seeds of *A. tenerum* often have a slight depression.

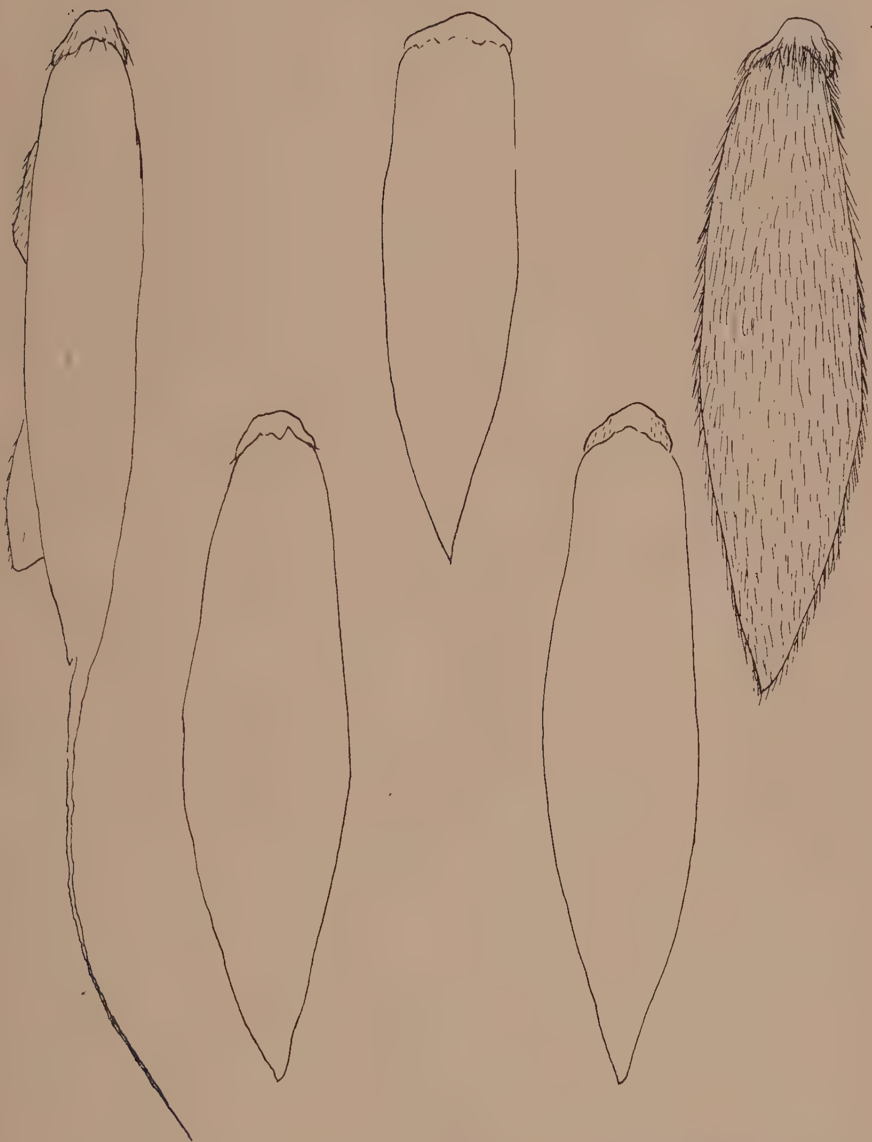
The basal end of the lemma is more actutely curved in seeds of the *A. tenerum* group (especially in A. No. 5), is broader in those of *A. repens*, and somewhat right-angled, as well as broad, in those of *A. Smithii*. The base of the lemma of the seeds of *A. cristatum* is broader in proportion to the length of the seed than is the case in other species.

Many species possess seeds with a few hairs at the apical end of the lemma. *A. dasystachyum* is the only species in which the lemma is pubescent over its entire surface. The length and number of hairs vary with the different forms. I have kept record of two forms which I numbered A. No. 4 and A. No. 10. Some seeds of these species are difficult to distinguish from seeds of the genus *Elymus*.



A. divergens. *A. cristatum.* *A. dasystachyum.*
A. No. 5. *A. Smithii.*
A. repens.

PLATE II.



A. divergens. *A. cristatum.* *A. dasystachyum.*
A. repens. *A. Smithii.*

PLATE III.

A. Richardsonii. (*A. No. 9.*)

A. tenerum. (*A. No. 12*)

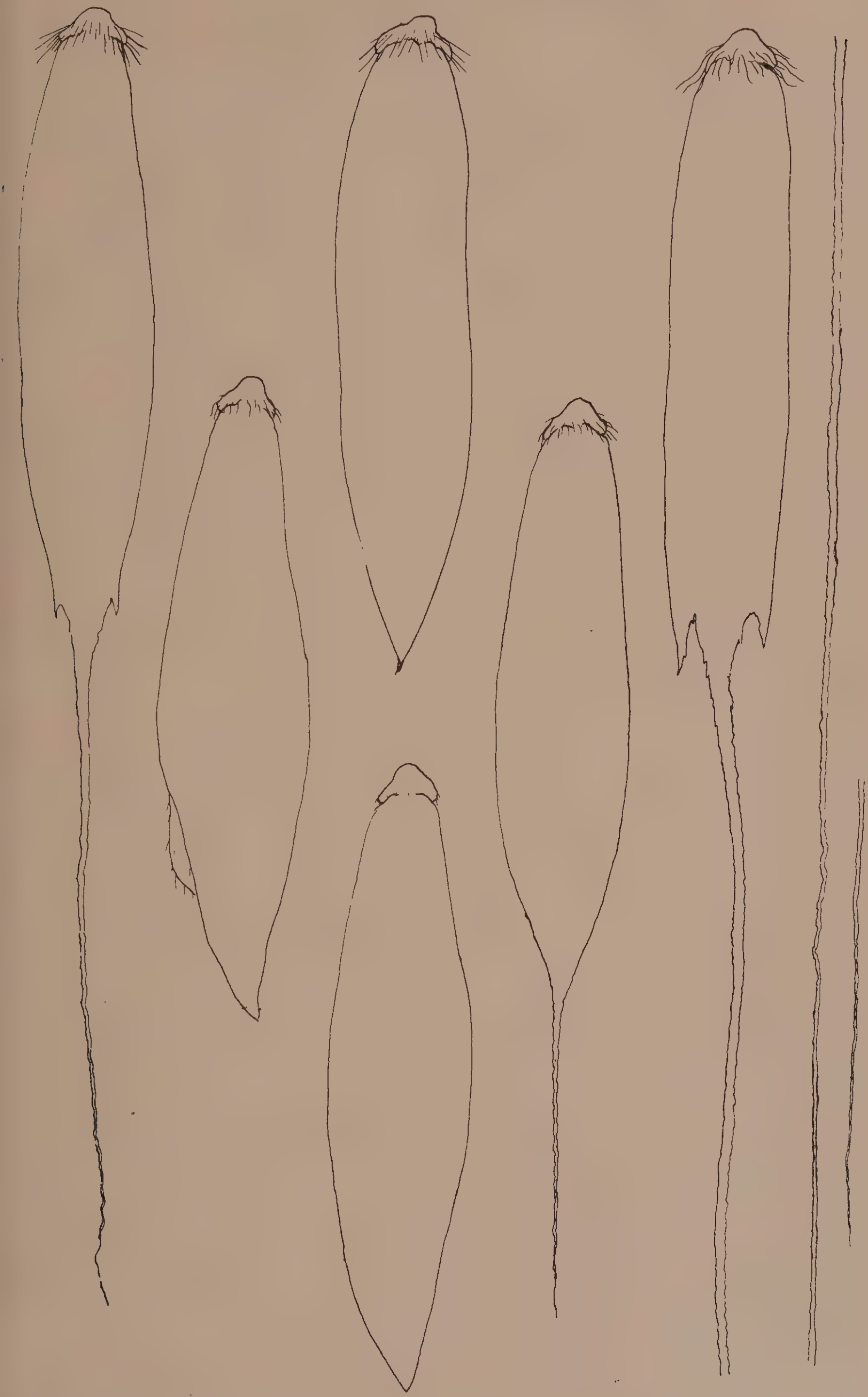
A. No. 11.

A. No. 5.

A. caninum.

A. Richardsonii. (*A. No. 9a.*)

PLATE IV.



A. Richardsonii.
(*A. No. 9.*)

A. tenerum.
(*A. No. 12*)

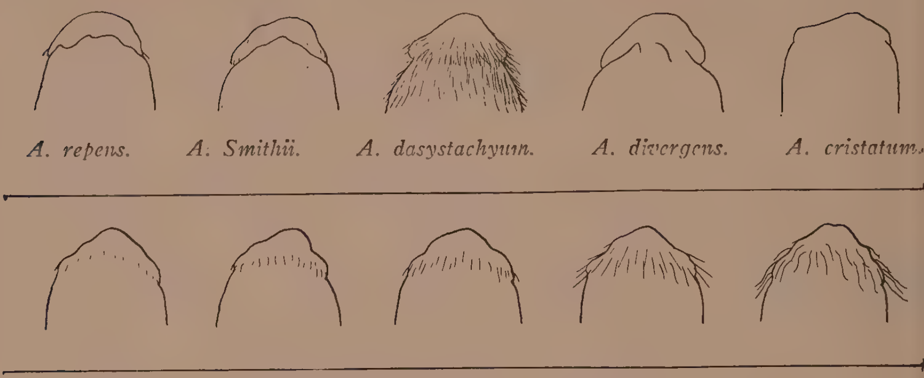
A. No. 11.

A. No. 5.

A. caninum.

A. Richardsonii.
(*A. No. 9a.*)

PLATE V.



Variations in *A. tenerum* — *A. Richardsonii.*
PLATE VI.

The mid-nerve of the lemma in seeds of *A. repens* and of *A. cristatum* is prominent and gives the seed a keeled appearance. These two species are the only common ones in which the lemma is keeled. Naturally, mature seeds show this character more than do immature ones.

Great variation is shown in the presence and length of the awn. Approximately ninety-eight per cent of the seeds of *A. repens* that I have studied are awnless, but occasionally one finds a seed with an awn even as long as the lemma. This awn is very rigid and carries fine but stiff teeth. The seeds of *A. divergens* have a divergent awn which varies from one to two times the length of the lemma. Seeds of *A. Smithii* and of *A. cristatum* are sometimes awn-pointed whereas those of *A. dasystachyum* seldom, if ever, possess an awn. The species and varieties of the *A. tenerum* group show lemmas with various lengths of awn.—those of A. No. 5 possessing no awn, those of A. No. 12 no awn or an awn-point, those of A. No. 11 and *A. caninum* a short awn (approximately one-quarter the length of the lemma), and those of *A. Richardsonii* an awn three to four times the length of the lemma. The lemma in seeds of the last-named species extends past the apex of the palea and ends in a trifurcate part of which the central prong extends to form the awn. This apical formation of the lemma is quite characteristic but may be somewhat damaged by commercial handling.

Palea—The palea of the seeds of *Agropyron* is slightly smaller and thinner than the lemma and is two-keeled, ciliate on the keels. The margins of the palea are folded under, giving one the impression that the toothed keels are the edges of the palea. While a distinction of species might be made by the teeth on the keels, this character can be observed only under high magnification. However, it is an additional means of identification. Dahlberg (*1*) states "The hairs on the edge* of the palea have a distinctive shape for each of the three species and are very useful as a determining factor. Those of *A. repens* are rather short, stout, and somewhat blunt. Those of *A. Smithii* are about as coarse as those of *A. repens* but noticeably longer, thus making them appear more slender. On *A. tenerum* the hairs are finer, closer together, and more acutely pointed than in the

*Dahlberg evidently means keels.

case of the two others." These spines are valuable in identifying seeds of *A. cristatum*. In this species, the keels bear large, well-spaced spines, larger and further apart than are the teeth of any other species. The palea and lemma are markedly rolled.

In most forms of *Agropyron* the palea has few hairs and those are at the apex. *A. dasystachyum*, with a hairy palea, is one exception to this. In some forms of *A. Smithii* the palea is free from hairs (A. No. 6), whereas in others it is quite hairy (A. No. 7). The seeds of these two forms appear similar in all other respects. Rarely do seeds of *A. tenerum* have a hairy palea (see table 1). In those of A. No. 2 the hairs on the palea are many and appear in a more or less definite V-shaped arrangement. Seeds of the A. No. 3 variety have the palea covered with hairs which appear hooked or curved. The palea of seeds of *A. repens* not only is free from hairs, except for a few at the apex, but in mature seeds it is glandular (pitted with oil cells). The apex of the palea is characteristic for seeds of *A. Smithii* in that it is always indented and frequently cleft. Paleas of seeds of *A. tenerum* and of *A. repens* may occasionally be slightly indented but are ordinarily truncate, those of *A. repens* broadly so, of *A. tenerum* narrowly.

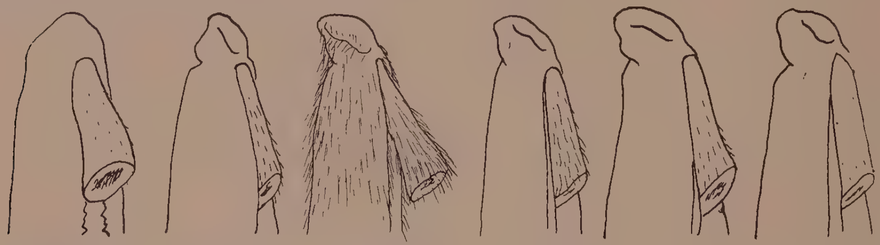
Rachilla—The length of the rachilla varies in all seeds of *Agropyron*, the lowest seeds in the spikelet having the shortest rachilla, the uppermost, the longest. In seeds of *A. repens* the rachilla is parallel-sided. That of seeds of the *A. tenerum* group and of *A. divergens*, of *A. cristatum*, and of *A. dasystachyum* has a slight flare on the upper end, whereas in seeds of *A. Smithii* it expands gradually from the bottom up and fills the entire space between the two edges of the lemma. The junction of the sides of the lemma at the base of the rachilla is V-shaped in seeds of the *A. tenerum* and of the *A. Smithii* groups, and U-shaped in those of *A. repens* and of *A. cristatum*. Due to this U-shape and the parallel-sidedness of the rachilla, seeds of *A. repens* have spaces between the rachilla and the sides of the lemma. In seeds of *A. cristatum* the lemma and palea are so curved that the rachilla is forced up and appears to sit on top of the incurved edges of these glumes. The rachilla in the case of *A. repens* is appressed to the palea and in the other species it occupies an intermediate position.

The pubescence of the rachilla is one of the most useful distinguishing characters. In seeds of *A. repens* and *A. cristatum* the rachilla has few hairs and those are short, fine ones with a rather large base. In the case of A. repens glandular cells may be observed at the base of the hairs. The rachilla of seeds of *A. Smithii* is hirsute with hairs much like those of the two varieties just described, but larger, stronger and more numerous. The hairiness of the rachilla in the *A. tenerum* group varies from a few short, inconspicuous, silky hairs in A. No. 5 to a condition which might be termed pilose in A. No. 12 and A. No. 11 to longer hairs in *A. caninum*, and finally to long, matted hairs in the case of *A. Richardsonii*. These variations parallel those noted in the case of the hairiness of the callus.

Caryopsis—As a result of commercial cleaning, some seeds appear in samples with the glumes partly or entirely missing. As the palea is attached to the caryopsis, part of that glume is more likely to remain. In nearly

every case the embryo is damaged. I know of no means whereby the free grains of the different species may be distinguished with certainty.

All species of *Agropyron* appear subject to attack by ergot and quite frequently ergotized seeds appear in samples. *A. repens* and *A. Smithii* seem to be more subject to this than do the others.



A. cristatum. *A. divergens.* *A. dasystachyum.* *A. tenerum.* *A. Smithii.* *A. repens.*

A. cristatum. *A. divergens.* *A. tenerum.* *A. Smithii.* *A. repens.*

PLATE VII.

CONDENSED DESCRIPTIONS OF THE MORPHOLOGICAL CHARACTERS OF THE SEEDS OF THE SPECIES OF AGROPYRON ALREADY REFERRED TO.

A. repens. The seed is boat-shaped due to the prominence of the mid-nerve which gives the lemma a keeled appearance. In colour it is a brownish yellow of a deeper shade than are the seeds of any other species of *Agropyron*. The callus, which is plainly delineated and shiny, is, together with the rest of the lemma, entirely free from hairs. The palea is glabrous with the exception of soft spines on the keels and occasional hairs at the apex. The lemma is U-shaped at the base of the parallel-sided rachilla and there are spaces between the rachilla and the sides of the lemma. On the rachilla are soft, short broad hairs.

A. cristatum. The seed of this species might be confused with that of *A. repens* if one considered only the characters already described for the lemma, the callus, the palea and the rachilla. However, the seed of *A. cristatum* is shorter than that of *A. repens* and its basal part is broad in proportion to the length of the seed. The lemma is much incurved, forcing the rachilla up from the palea. The spines on the keels of the palea are stiff and prominent.

A. tenerum. The glumes of the seed of *A. tenerum* are more flattened than those of the two species described above, and frequently the lemma is twisted slightly from its position, making the seed unsymmetrical. The callus, which is more pointed than that of most species of *Agropyron*, has a fringe of silky hairs. The rachilla has similar hairs, longer and silkier than those on the rachilla of *A. repens* or *A. Smithii*. The lemma is V-shaped at the base of the rachilla. The apex of the lemma varies from a sharp point to an awn twice the length of the lemma proper.

A. Richardsonii. This species and *A. tenerum* intergrade. The description just given for seeds of *A. tenerum* is applicable to those of this species, except that the hairs on the callus and on the rachilla are two to three times as long, and the apex of the lemma is trifurcate, the central nerve projecting to form an awn three to four times the length of the lemma proper.

A. divergens. The seeds resemble those of *A. tenerum* but the lemma carries a divergent awn approximately three times its length. Because of this divergence the lemma is twisted. The seed is not mature until September and therefore is seldom seen in commercial seed stocks.

A. Smithii. The seeds of this species are coarser in appearance than those of any of the above species. Maturing several weeks later than *A. tenerum* and *A. repens,* the seeds are commonly found in commercial seed of Western Rye Grass and of Brome, but usually appear greener in colour, are more succulent in texture, and, in the majority of cases, lack a ripened caryopsis. There are broad, soft hairs on the rachilla and on the sides of the callus but none on the centre of the callus. The rachilla flares from base to apex and fills the space between the two sides of the lemma. In some varieties the palea is hairy, in others it is glabrous. The lemma is seldom, if ever, awned.

Descriptions of the Seeds of Less Common Species of Agropyron

To avoid making the foregoing descriptions and comparisons confusing, by the introduction of more detail than was necessary, I omitted treating of the species less commonly found. These may be described briefly as follows:

A. alaskanum, Scribner & Merr. The specimens in the National Herbarium were from Northern British Columbia and Alaska.

The lemma has five nerves, distinct and hairy. In the case of some plants there are a few hairs between the nerves. The callus is narrowly truncate and has a fringe of hairs equal in length to those of A. No. 12; the commonest form of *A. tenerum.* The ventral part of the callus is hairy. The apex of the lemma is awn-pointed or has an awn not exceeding one-third the length of the lemma, with stout hairs. The palea is glabrous, except on the keels. The spines are fairly long but soft and closely spaced in continuous uniform rows. The rachilla is hairy as in A. No. 12. The glumes are flat at the apex. This would appear to be my A. No. 8 form. Very rarely do seeds of this species occur in commercial stocks.

A. violaceum Horn. The plants in the National Herbarium were from British Columbia, Yukon, Alaska, Shores of Hudson Bay, and Labrador.

The lemma is covered with soft hairs of medium length, the longest ones being on the sides of the callus and the margins of the lemma. The humps just above the callus may be bare. In some plants the majority of the hairs at the apex, or even on the upper half of the lemma, are on the nerves. The apex is awn-pointed. The palea is glabrous with the exception of a few hairs at the very apex, and soft, hair-like spines on the keels. It is thin in texture. The rachilla is generally parallel-sided, broadening slightly at the top, and discovered with long, stiff hairs. The glumes are flat at the apex.

A. albicans, Scrib. and Smith. The specimens at the National Herbarium were from Jasper Park and the Crow's Nest Pass.

The lemma is covered with soft hairs which increase in number and length from the basal end up to the apex. There are long hairs on the sides of the callus but few at the centre of the callus or on the hump of the lemma above. The palea is covered with soft, fine hairs. The rachilla is parallel-sided, except where it enlarges slightly at the top. The hairs on it are of medium length. The glumes are flattened at the apex. The pubescence of the seed cannot be noticed by the naked eye.

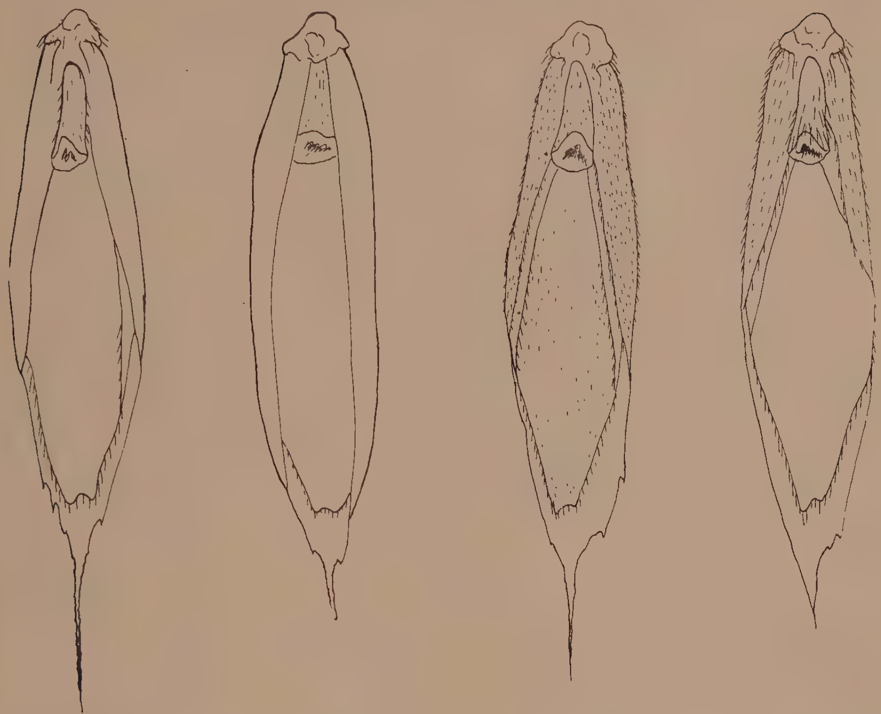
A. acadiense, Hubbard. The specimens at the National Herbarium were from Nova Scotia.

The lemma is very bare of hairs, having one or two at the edges of the callus only. It is keeled and ends in a stubby awn-point which appears to the naked eye like a longer awn broken off. The callus is free from hairs and thus might be confused with that of *A. repens.* However, it is in line with the back of the seeds and not the centre as in *A. repens.* Also, there is a distinct depression of the lemma immediately above the callus. The palea is glabrous and glandular, with fine, soft hairs on the keels. The rachilla is broader than in *A. repens* and fills the space between the sides of the lemma which tend to close over it. The rachilla is not appressed to the palea but the lemma curves above it. The hairs on the rachilla are soft and short, resembling those on A. No. 5 more than those on *A. repens.* The glumes are flattened at the apex whereas those of seeds of *A. repens* are more curved.

A. inerme, Scrib. and Smith (Rydb.). The lemma is glabrous except for occasional hairs at the apex. The callus is free from hairs in the centre but is tufted at the sides. There is a deep depression above the callus. The lemma is not awned. The palea is glabrous except for occasional hairs at the apex. The rachilla resembles that of A. No. 5.

Variation within the Species of Agropyron

Reference to manuals of botany shows that most authors have not only differences of opinion regarding the classification of the grasses in the genus *Agropyryon,* but they also state that the genus contains many more American species and varieties than those they describe and classify. Hitchcock states that there are twenty-five, and Sampson thirty-five, American forms, and all authors agree that these are most prevalent on the western prairies. It is evident that there is variation within the described species and probably no species shows more variation than does *A. tenerum.* Presumably this is so because it is one of the commonest forms and because it has been brought under cultivation, with the resultant selection of many strains. Forms including A. No. 2, A. No. 3, A. No. 5, A. No. 11, A. No. 12, and A. No. 12-a, also strains in the plots at the Experimental Farms and Agricultural Colleges, and *A. caninum,* L., *A. caninum,* variety *pubescens,* Scribner and Smith, *A. Richardsonii* Schrad., and *A. inerme,* Scribner and Smith (Rydb.) possess the same general shape, colour, texture, shape of callus and of rachilla, etc., but vary through a graduated series, as regards the pubescence of the callus and of the rachilla, and the absence, presence or length of awn. Dr. Hitchcock has suggested *A. inerme* for my *A. No.* vv form but the seeds on the plants of *A. inerme* in the National Herbarium,



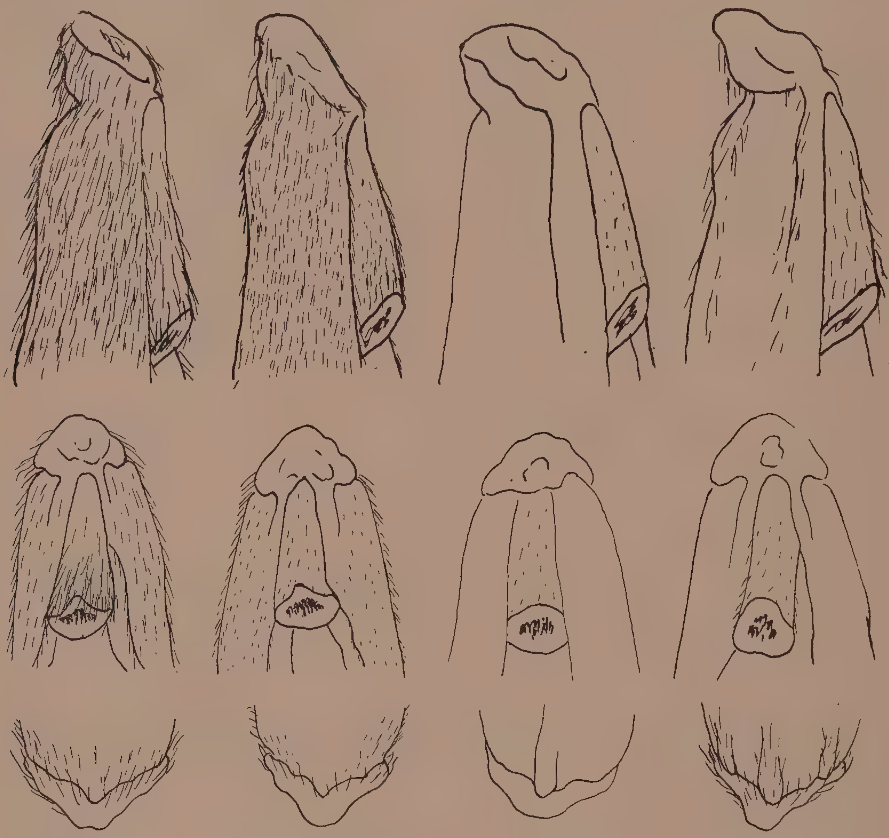
A. alaskanum. *A. acadiense.* *A. albicans.* *A. violaceum.*

PLATE VIII.

A. alaskanum. *A. acadiense.* *A. albicans.* *A. violaceum.*

PLATE IX.

Ottawa, resemble very closely my A. No. 5. Mrs. Agnes Chase, long associated with Dr. Hitchcock, states that *A. caninum* and *A. tenerum* seem to intergrade, the difference in the two species being mainly in the length of the awn.



A. alaskanum. *A. acadiense.* *A. albicans.* *A. violaceum.*

PLATE X.

Many, or all of these varieties appear to breed true. On no plant have I found more than one type of seed. Upon my discussing this question with Dr. Malte, Botanist in charge of the Canadian National Herbarium, he stated that he agreed with my findings and related how on one occasion he had stood in a vacant lot in Calgary and, without moving from his one position, had gathered six different strains of *A. tenerum,* which upon planting bred true.

This field of study is an enormous one and all I can do now is to introduce the subject and to quote Dr. Malte on similar work he did on Timothy:

"The study of the individual variation of this timothy seed reveals many interesting things. Scores of very distinct seed types, every one uniform, within each individual plant, can easily be distinguished............. It must be mentioned especially that the plants collected were growing under practically the very same conditions in the same kind of soil, and

that any influence of different weather conditions during the ripening period on the differentiation of the seed types is out of question................The difference as to shape, colour and size between the seed of different plants must have their foundation in the very morphology of the plant. They must be characters of constitutional quality, characters which form an essential part of that biological unit called biotype."

SUMMARY

1. Brome grass seed brought seed of *A. repens,* Couch Grass, with it from Russia.

2. *A. tenerum,* Vasey, Slender Wheat Grass, a native grass of the same genus, has been successfully used as a forage crop and is known in the commercial seed trade as Westetrn Rye Grass.

3. Many other wheat grasses (*Agropyron*) are native to the prairies of western Canada.

4. Analyses of seed samples at the Winnipeg Laboratory of the Seed Branch, Canadian Department of Agriculture, show that forty-five per cent of all samples of Brome and five per cent of the samples of Western Rye Grass contain seeds of Couch Grass. Field inspection of standing crops shows approximately the same percentages.

5. Many species, *A. tenerum* especially, show variant sub-species which apparently breed true.

6. Seeds of the various species of *Agropyron* cannot be distinguished from one another except under magnification.

7. Seeds of *A. dasystachyum* may be recognized by the pubescence over the entire seed.

8. Seed of *A. divergens* may be identified by its divergent awn which twists the lemma and the palea out of position. This seed, ripening later than does that of the other species, seldom occurs in the commercial seed stocks.

9. Seeds of *A. cristatum* may be identified by their smaller size, by the palea and lemma which are markedly rolled, by the spines on the keels of the palea, and by the broad base of the seed.

10. For seeds of *A. repens, A. Smithii* and *A. tencrum* no single character may be chosen as an infallible indicator, but the student must become familiar with the shape and the pubescence of the rachilla, the delineation and pubescence of the callus, the tip of the palea, and the awn.

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PESANTEUR AU BOISSEAU DE L'AVOINE: FACTEUR INFLUENCANT LE POURCENTAGE D'ECALE*

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Tous les esprits avertis reconnaissent que la valeur d'une variété d'avoine doit se mesurer largement à son pourcentage d'écale. Tous savent également que ce pourcentage est fortement influencé par de nombreux facteurs tels que la variété, la température, etc.

On peut se demander s'il existe quelques relations entre la pesanteur au boisseau d'une variété quelconque et son pourcentage d'écale. C'est le point que nous nous proposons d'étudier dans les lignes qui suivront.

Hunt (*1*), en 1909, Warburton, (*5*), en 1907, trouvent qu'il n'existe pas une corrélation "nécessaire" entre la pesanteur au boisseau et la proportion d'amande bien que pour une variété donnée, ils en soient arrivés à une certaine corrélation. La pesanteur au boisseau la plus élevée, en effet, était associée au pourcentage le plus fort en amande.

Love (*2*), lui, trouva les deux coefficients suivants:

$$r = .237 \pm .058$$
$$r = .188 \pm .055$$

Bien qu'ils ne soient point significatifs, le signe — (négatif) indique une tendance vers un faible pourcentage d'écale quand la pesanteur au boisseau augmente.

Stoa (*4*), fait mention quelque part du fait suivant: la pesanteur au boisseau élevée indique généralement une avoine de haute qualité et riche au point de vue alimentaire.

Enfin Love et Craig (*3*), après avoir étudié le même problème, concluent que la proportion d'écale ne dépend pas "absolument" de la pesanteur au boisseau.

L'auteur du présent travail ayant étudié un groupe de variétés tardives, essayées au collège Macdonald, Qué., obtint comme coefficient de corrélation:

$$r = .3504 \pm .045$$

A cette même Station encore, on conduit une expérience connue sous le nom "d'Expérience sur les Dates de Semis". Etudiés dans une table corrélative, ces résultats donnèrent comme coefficient:

$$r = -.842 \pm .036$$

Enfin, des données gracieusement fournies par le Chef de la division des Céréales, Ferme Expérimentale Centrale, Ottawa, M. L. H. Newman, étudiées également dans une table corrélative, donnèrent le coefficient suivant:

$$r = -.728 \pm .038$$

Ainsi qu'on peut le voir, ces trois coefficients sont hautement significatifs.

L'auteur tenta d'obtenir de nouveaux éclaircissements sur le sujet en comparant la pesanteur au boisseau moyenne et le pourcentage d'écale moyen d'un groupe de variétés expérimentées durant plusieurs années.

Comme on pouvait s'y attendre, le facteur "variété" y joue un rôle si important que toute conclusion devient impossible en ce qui regarde le pourcentage d'écale et la pesanteur au boisseau. Toutes les possibilités se

*Resumé d'un chapitre d'une thèse sur "l'Etude des Facteurs Influencant le Pourcentage d'Ecale dans l'Avoine". Présentée à la Faculté des Etudes graduées et des Recherches, Université McGill, pour l'obtention du M.S.A.

†Rédacteur à "La Terre de Chez Nous", Organe officiel de l'U.C.C.

Variété	Pesanteur au Boisseau (moyenne)	Pourcentage D'Ecale (moyen)
Alaska (G)	36.88	22.83
Banner (Dery)	32.24	29.10
Daubeney (G)	32.83	25.62
Fifty Pound Black (R)	30.50	34.75
Garton's Abundance	33.18	27.98
Joanette (G)	32.19	26.77
Ligowo (F)	32.81	28.59
Siberian (G)	31.84	27.99
Early Gothland (Waugh)	36.21	30.53

rencontrent dans un pareil groupement:

Pesanteur	élevée	et	faible pourcentage	d'écale:	Alaska
"	"	"	fort "	"	Early Gothland
"	faible	"	" "	"	Fifty Pound Black.
"	"	"	faible "	"	Siberian
"	moyenne	"	" "	"	Daubeney
"	"	"	et pourcentage d'écale moyen:		Banner (Dery)

L'étude de la pesanteur au boisseau en rapport avec son % d'écale par la méthode dite "au-dessus" et "au- dessous" de la moyenne fut beaucoup plus concluante.

Variété	Pesanteur Moyenne Au Boisseau	Pourcentage D'Ecale Moyen "Au-Dessous"	Pourcentage D'Ecale Moyen "Au-Dessus"
Alaska (G)	36.88	23.52	22.28
Banner (Dery)	32.24	30.24	28.20
Daubeney (G)	32.83	26.84	25.35
Fifty Pound Black	30.50	36.04	33.00
Garton's Abundance	33.18	28.06	27.94
Joanette (G)	32.19	28.07	25.48
Ligowo (E)	32.81	28.03	28.92
Siberian (G)	31.84	29.66	26.34
Early Gothland (W)	36.21	31.03	29.87

Si l'on fait exception de la Ligowo (E), où un plus faible pourcentage d'écale se rencontre avec les années où le poids par boisseau est "au-dessous" de la moyenne et de la Garton's Abundance où la différence n'est guère sensible, le pourcentage moindre d'écale suit toujours la pesanteur la plus élevée au boisseau.

Conclusions

Ces résultats prouvent clairement qu'il existe, au moins dans les données présentement étudiées, une relation étroite entre ces deux caractères.

L'on peut dire sans crainte d'erreur que, dans une variété donnée, la pesanteur au boisseau la plus élevée est toujours associée au plus faible pourcentage d'écale.

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CONCERNING THE C.S.T.A.

Notes and News

D. A. MacGibbon (McMaster '11), Professor of Political Economy at the University of Alberta since 1919, has accepted an appointment as one of the three commissioners constituting the newly organized Grain Board. T. J. Harrison (Manitoba '11), Professor of Field Husbandry at the Manitoba Agricultural College, has been appointed Assistant Grain Commissioner representing Manitoba.

P. H. H. Gray, M.A., a graduate of Queens College, Oxford, has been appointed head of the Bacteriology Department at Macdonald College (Faculty of Agriculture, McGill University) and has recently arrived to assume his duties. Professor Gray comes to Macdonald from the Rothamsted Experimental Station, where he has been engaged in research work in soil microörganisms and general microbiology. With his interest in soil work, he should be a valuable addition to the staff of Macdonald College, where a special research project on Quebec soils is now being conducted.

F. B. Hutt (Toronto '23), Associate Professor of Poultry Husbandry in the University of Minnesota, has been awarded the first "Poultry Science Research Prize." This prize of $100.00 will be awarded annually to the member of the Poultry Science Association who has published the most significant contribution to the field of poultry research. The article upon which the award was based appeared in *Poultry Science,* May 1, 1929, its title being "Sex Dimorphism and Variability in the Appendicular Skeleton of the Leghorn Fowl."

W. F. Jones (Toronto '23), formerly Chief Technical Adviser of the Chateau Cheese Co., Ltd., Ottawa, has been appointed General Manager of the Ottawa Dairy Co. Ltd., Ottawa, Ont. Mr. Jones took over his new duties on October 21st.

W. P. Thompson (Toronto '10), Professor of Biology at the University of Saskatchewan, has been granted leave of absence for twelve months and is taking a special course of study in the Department of Genetics, University of California, Berkeley, Cal.

E. E. Brockelbank (Saskatchewan '22) is taking graduate work at the University of Minnesota.

W. Southworth (Toronto '12) has been appointed to a position on the research staff of the Department of Plant Breeding at the University of Wales, Aberystwyth, Wales. His mailing address is Agricultural Buildings, Alexandra Road, Aberystwyth, Wales, Great Britain.

Auguste Scott (Montreal '24) has received the M.Sc. degree from the University of Toronto. Mr. Scott took his graduate work in soil chemistry at the University of Toronto under a T. Eaton Company scholarship awarded through the C.S.T.A.

B. G. Montserin (McGill '27) is continuing graduate work towards the Ph.D. degree in the Department of Botany, University of Toronto.

Dr. J. A. Ruddick, Dominion Dairy and Cold Storage Commissioner, is leaving Ottawa shortly for the Island of Jamaica where it is understood he will spend the winter enjoying a much needed rest. While there he expects to look into the possibilities for the establishment of an enlarged trade in dairy products between Jamaica and Canada.

N. A. Drummond (McGill '28) and K. A. Harrison (Toronto '24), who are both taking graduate work at the University of Toronto under T. Eaton Company scholarships awarded through the C.S.T.A., have the following mailing addresses: N. A. Drummond, 59 Prince Arthur Avenue, Toronto, Ont., and K. A. Harrison, 73 Hampton Avenue, Toronto 6, Ont.

E. G. Bayfield (Alberta '23) who has been taking graduate work at the Agricultural Experiment Station, Wooster, Ohio, as National Milling Company Fellow, is doing special work at the Ohio State University. His address for the next three months will be Department of Soils, Ohio State University, Columbus, Ohio, after which time he expects to return to Wooster.

H. R. McLarty (McMaster '16), is taking graduate work at the University of Illinois. His mailing address is 706 California Street, Urbana, Ill.

Abel Raymond (Montreal '12) has changed his address to 2 Chauveau Street, Quebec, P.Q.

E. N. Blondin (McGill '14), District Sales and Service Representative for the Ralston-Purina Company, has changed his mailing address from Huntingdon, P.Q., to 7 Northcliffe Avenue, Montreal, P.Q.

C. A. Lamb (British Columbia '21), formerly teaching Agriculture and Science at Port Haney, B.C. High School, has been appointed Assistant in Agronomy at the University of British Columbia, Vancouver, B.C.

G. H. Bowen (McGill '23) has changed his address to Box 306, International House, 500 Riverside Drive, New York City.

Fernand L. Godbout (Laval '25) has received the M.Sc. degree in Plant Pathology from McGill University and has been appointed permanent Plant Pathologist for the Quebec Department of Agriculture. He can be addressed at either 702 Jarry Street, Montreal, P.Q., or at Macdonald College, P.Q.

A. S. McFarlane (McGill '28) has changed his address to Fishers Experimental Station, Halifax, N.S.

J. R. Fryer (Toronto '13), who has been taking graduate work at the University of California for the past year, has resumed his duties as Associate Professor of Genetics and Plant Breeding at the University of Alberta, Edmonton, Alta.

Professor J. P. Sackville of the University of Alberta, President of the C.S.T.A., will attend local branch meetings of the Society in eastern Canada during November, at the following points:—Amherst, N.S., November 13th; Quebec, P.Q., November 15th; Montreal, P.Q., November 16th; Ottawa, Ont., November 16th. A meeting of the Executive Council of the Society will be held at Toronto on November 23rd.

R. W. Stuckey (McGill '28) who has been Colonial Office Scholar at the Imperial College of Tropical Agriculture, Trinidad, for the past year has been appointed Agricultural Officer to the Uganda Protectorate and sails from England to take up his new duties on November 7th.

J. S. Shoemaker (Toronto '21) has recently been appointed to the horticultural staff of the Ohio State University, Columbus, Ohio, this new position being undertaken in addition to his present duties as Associate Horticulturist at the Agricultural Experiment Station, Wooster, Ohio.

G. L. Art (Saskatchewan '25) has changed his mailing address to 1301 Elliott Street, Saskatoon, Sask.

E. R. Bewell (Manitoba '14) has resigned his position as District Agriculturist at Courtenay, B.C., and is now Agricultural Adviser and Salesman for Fertilizer Products Ltd., in Vancouver, B.C. His mailing address is 1724-17th Avenue, New Westminster, B.C.

Applications for Membership

The following applications for regular membership have been received since October 1, 1929:—

Finlayson, L. R. (McGill, 1929, B.S.A.) Macdonald College, P.Q.
Harrison, A. L. (Toronto, 1929, B.S.A.) Fredericton, N.B.
Holcomb, R. (McGill, 1929, B.S.A.) Ste. Anne de Bellevue, P.Q.
Hopkins, J. W. (Alberta, 1929, B.Sc.) Edmonton, Alta.
Mackenzie, A. W. (Toronto, 1923, B.S.A.) Amherst, N.S.
McMaster, N.B. (McGill, 1929, B.S.A.) Ottawa, Ont.
Tyson, E. G. (Alberta, 1929, B.Sc.) Stavely, Alta.

Vaccancies in Dominion Department of Agriculture

The Civil Service Commission at Ottawa is advertising the following vacancies in the Dominion Department of Agriculture. Applications should be addressed to the Secretary of the Commission and received not later than November 7, 1929:—

Assistant Chemist (Soil Analysis). Initial salary $2,220 per annum up to a maximum salary of $2,700. To be located in Saskatchewan.

Plant Pathologist (Bilingual). Initial salary $2,520 per annum up to a maximum salary of $2,880. To be located in Quebec.

Two Junior Chemists. Initial salary $1,800 up to a maximum salary of $2,160. To be located at Ottawa.

Tobacco Inspector (Bilingual). Initial salary $1,800 per annum up to a maximum of $2,160 per annum. To be located in Quebec.

Experimental Farm Assistant. Initial salary $1,620 per annum up to a maximum of $1,920 per annum. To be located at Harrow, Ont.

Applications for the following vacancy will be received until November 14th:

Junior Entomologist. Initial salary $1,620 per annum up to a maximum of $1,920. To be located at Chatham, Ont.